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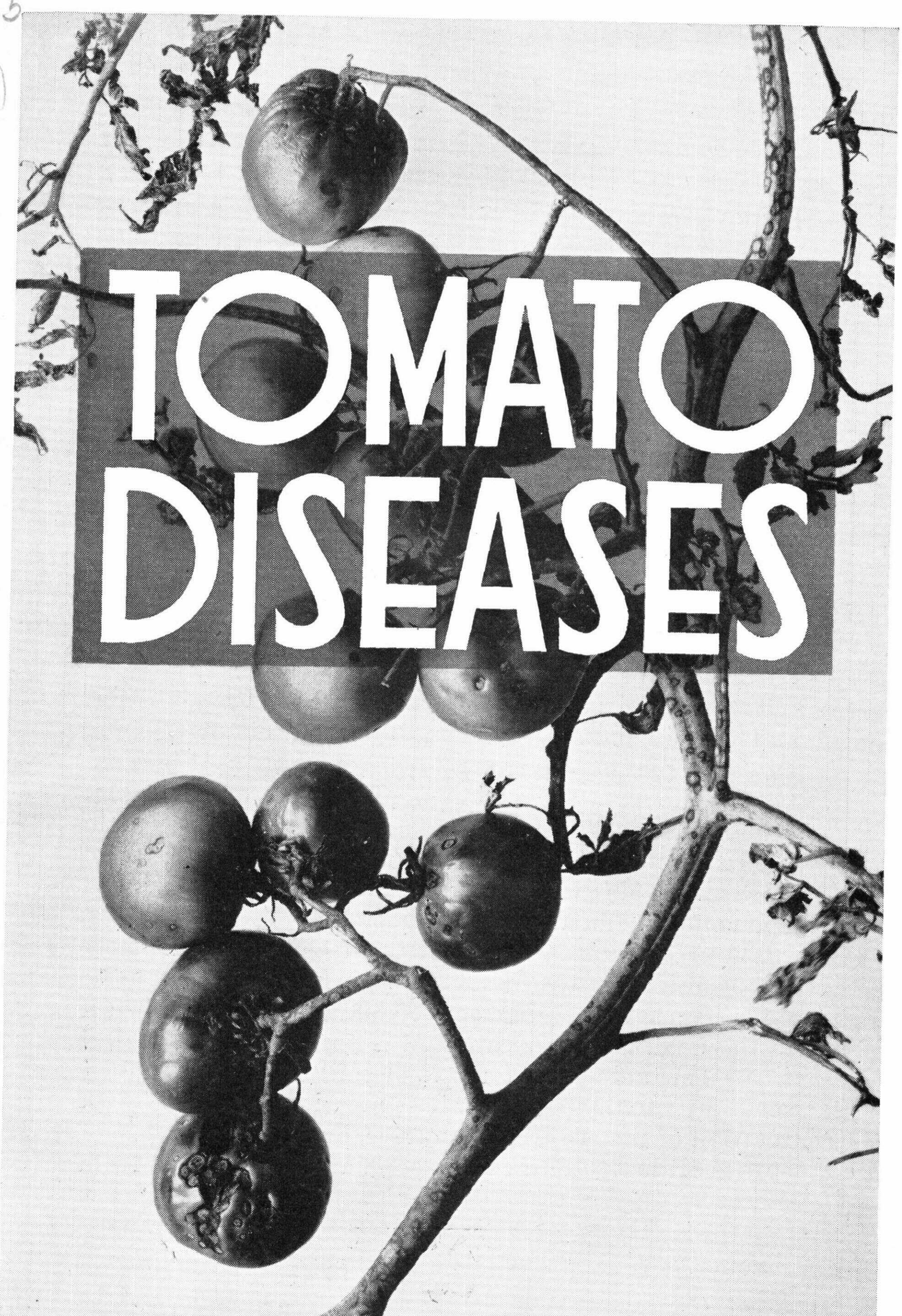
TOMATO DISEASES



FARMERS' BULLETIN NO. 1934
U.S. DEPARTMENT OF AGRICULTURE

PREVENTION OF LOSSES from diseases is a major factor in obtaining the maximum production of tomatoes—one of the Nation's most valuable vegetable crops and one of especially high nutritional importance because of its vitamin contributions, including not only the vitamin C that first recommended it to dieticians but also vitamins A, B_1, G, and the pellagra-preventive factor. Diseases not only deprive the Nation of large quantities of tomatoes but also waste many man-hours of labor that are ineffective when good crops are not brought to maturity.

This loss and waste can be avoided only when the diseases that cause them are understood and effectively combatted. To help meet these needs, this bulletin describes the diseases that commonly affect tomatoes and the methods known for reducing the losses they cause.

Tomato diseases are caused by fungi, bacteria, viruses, and certain unfavorable conditions of soil or climate. Diseased plants usually cannot be cured, but it is often possible to prevent infection. The most effective and economical method of growing healthy tomatoes is to use resistant varieties; but, as varieties resistant to most diseases are not available at present, growers must depend upon other methods of reducing losses.

The prevention of diseases in the seedbed is particularly important, since the losses from disease are likely to be much less severe if disease-free tomato plants can be set in the field. When clean seed is protected by chemical treatment and planted in clean soil, a crop of healthy seedlings usually results. These practices, combined with rotation of the crop, clean culture, and the proper use of sprays or dusts, are the best safeguards against loss from disease.

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TOMATO DISEASES

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IMPORTANCE OF TOMATO DISEASES

TOMATO DISEASES annually cause heavy losses to one of the most important and widely distributed vegetable crops in the United States. The tomato has long been grown extensively in this country, but since its high and varied vitamin content has become known, it has become even more important in meeting the Nation's nutritional requirements. Its contributions to food supplies are now considered essential.

In 1940 more than 600,000 acres were planted to tomatoes, and the estimated farm value of the crop was approximately $56,600,000.[1]

[1] U. S. Department of Agriculture Agricultural Statistics 1942.

Commercial tomato production is of three types: (1) The market crop, grown for shipment or local sale; (2) the crops grown for canning or processing into manufactured products; and (3) the forcing crop, produced in the greenhouse. In addition, tomatoes are one of the vegetables most commonly grown in home gardens.

Because of the popularity of the fresh fruit, commercial tomato crops are being grown in some part of the United States throughout almost the entire year. The earliest market crops are shipped from California, Florida, and Texas during the late fall, winter, and early spring; these are followed by shipments from various South Atlantic and South Central States until early summer. During this early market period a large forcing crop also is produced in greenhouses located chiefly in the East North Central, Middle Atlantic, and New England States. The later market crops of summer and early fall are distributed over a wide area but are grown most extensively in the North Central and North Atlantic States.

Tomatoes are the most important of the canning crops; over two-thirds of the total commercial acreage is used for canned and manufactured products. In 1940 the 15 most important tomato-canning States[2] on a basis of total production were, in the order named, California, Indiana, Maryland, New Jersey, Ohio, New York, Pennsylvania, Virginia, Utah, Arkansas, Missouri, Illinois, Delaware, Michigan, and Iowa.

Wherever tomatoes are grown they are subject to diseases that seriously reduce both the yield and the market value of the fruit. Diseases are of two general types, nonparasitic and parasitic. Nonparasitic diseases are caused by unfavorable environmental conditions, such as excessive moisture or drought, extremes of temperature, and lack or excess of certain mineral elements in the soil. Parasitic diseases are those caused by living organisms, chiefly bacteria and fungi, and by viruses. The parasitic group includes most of the common and serious tomato diseases.

Bacteria and fungi are microscopic organisms that obtain their food from the plant attacked or from decaying organic matter in the soil. They enter the plant through wounds and natural openings or directly penetrate the epidermis. After gaining entrance, they multiply within the plant tissues and produce specific symptoms, such as wilting of the plant, spotting, curling, or mottling of the leaves, or decay of the fruits.

The bacteria affecting tomatoes are one-celled, rod-shaped organisms that multiply with great rapidity in the plant. They occur on the surface of diseased plants either as exudates or as the result of a breaking open of the diseased tissue and, when so exposed, are readily spread to other plants by splashing rain, insects, or human beings.

The fungi are more complex organisms with threadlike vegetative growths (mycelia) from which are usually produced various types of structures that bear seedlike bodies known as spores. These spores are the reproductive stage of the fungi, and in the presence of moisture they can germinate and produce new infections. They are spread by wind, rain, drainage water, insects, and persons working among the plants.

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[2] See footnote 1.

Much remains to be found out about plant viruses; recent investigations indicate that they are complex protein substances which increase rapidly in the plant. In this and other respects they possess some characteristics of living organisms, but they are not thought of as living in the ordinary sense of the word. The individual virus elements are too small to be visible under the compound microscope and will pass through filters that retain the smallest known bacteria. The viruses are highly infectious, and many of them are readily transmitted by any means which serve to introduce a minute amount of juice from a virus-infected plant into a slight wound or abrasion in a healthy one.

The most common means of transmission are sucking insects, particularly aphids, and the brushing, handling, or pruning first of diseased and then of healthy plants. Some viruses, however, are transmitted by only certain species of insects and are not spread by contact with the plants; however, they may be transmitted by grafting a diseased shoot on a healthy plant. A few viruses are transmitted in the seed of certain of their host plants, but such transmission is comparatively rare. Most viruses do not survive in the soil, but soil transmission occurs in a few instances. Certain viruses, even though much alike in their chemical and physical properties, do not produce exactly the same symptoms on certain species of plants. Such viruses are known as strains of a single virus, in order to indicate a relationship between the different forms.

Since the bacteria and fungi are living organisms, they are destructive only when environmental conditions, particularly temperature and moisture, are favorable to their development and spread. These requirements are not the same for all the organisms that attack tomatoes, and, since this crop is grown under various environmental conditions, the diseases of most importance in one region may be almost unknown in another. Some viruses, such as the one causing curly top, are spread only by certain species of insects and are serious only in regions where conditions permit the existence of the insect carriers in large numbers.

Since ordinarily a diseased plant cannot be cured, control must be based on the prevention of the disease and of its spread. Many tomato diseases are not readily controlled after they are once well established in the field or greenhouse, but it is often possible to limit their occurrence by measures designed to prevent infection from contaminated seed and soil or from weeds that carry disease-producing organisms or viruses. When disease-free plants are set in clean soil, the likelihood of serious losses is at least greatly reduced.

This bulletin describes the diseases commonly affecting tomatoes in the field and greenhouse and gives measures recommended for reducing losses from them. As the methods of control vary with the nature and cause of the individual disease, it is necessary to determine what particular disease is responsible for an injury before applying control measures. An accurate diagnosis (see key, p. 79) is necessary in order to prevent waste of time and materials as by applying sprays or dusts to control such tomato diseases as fusarium wilt, which cannot be controlled by these methods. A diagnosis often requires a careful examination of the leaves, stems, and roots to be sure that all the symptoms characteristic of the disease are known. Many diseases are easily recognized, but others may be hard to identify. When there is any question as to the diagnosis, it is best to consult the local county agricultural agent or send specimens to the State agricultural college.

DISEASES CAUSED BY BACTERIA AND FUNGI

FUSARIUM WILT

Fusarium wilt, caused by *Fusarium oxysporum f. lycopersici* Snyder and Hansen, is one of the most prevalent and damaging diseases of tomatoes in many of the tomato-growing regions of the United States. The fungus causing the disease is found in the greenhouse as well as in the field and, when once introduced, can live for long periods in the soil. This organism generally does not cause serious losses unless soil and air temperatures are rather high during much of the season; the disease is most common and destructive where such conditions prevail. Plants of susceptible varieties either are killed or are so badly damaged that they produce little fruit. When fields become thoroughly infested with the fungus, they are no longer suitable for susceptible varieties of tomatoes.

In seeding plants fusarium wilt causes drooping and downward curvature of the oldest leaves, usually followed by wilting and death of the plant. Older plants in the field are infected at all stages of growth, but the disease generally becomes most evident when the plant is beginning to mature its fruit. The earliest symptom is yellowing of the lower leaves, first of those on only one side of the stem; also the leaflets on one side of the petiole may be affected before the others. The yellowed leaves gradually wilt and die and, as the disease progresses, yellowing and wilting continue up the stem until the foliage is killed and the stem dies. Frequently a single shoot is killed before the rest of the plant shows much injury (fig. 1). The stem of a wilted plant shows no soft decay, but if it is cut lengthwise, the woody portion

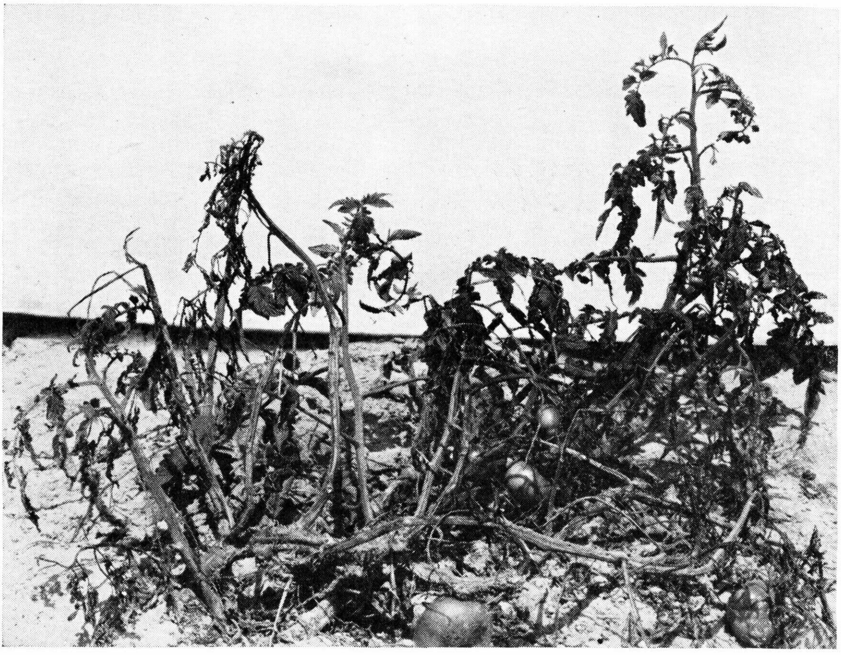

FIGURE 1.—Tomato plant showing symptoms of fusarium wilt. Some shoots have been killed, but others show only drooping leaves.

next to the green outer cortex shows a dark-brown discoloration of the water-conducting tissue (fibrovascular bundles), which is characteristic of the disease and helps in its identification (fig. 2). This discoloration often extends upward for some distance and is particularly evident in the petioles of wilted leaves at the point where they join the stem.

At times the same type of discoloration may be seen also in the water-conducting vessels in the central part of the fruit, but this is less common than in the stem and leaves. The fruits are not spotted.

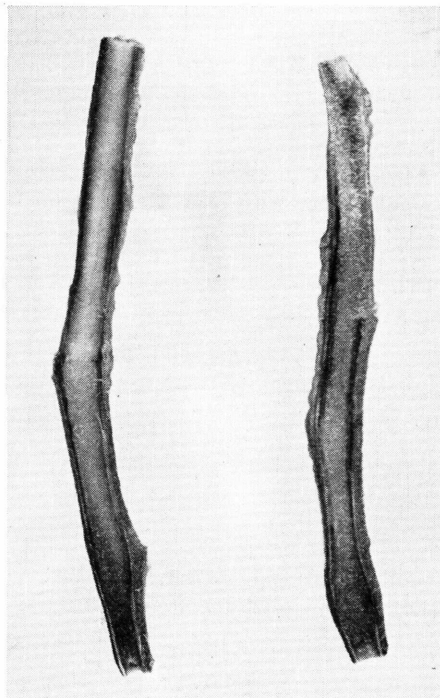

FIGURE 2.—Split stems of tomato plants affected with fusarium wilt. Note the discolored line of woody tissue between the pith and the outer green portion of the stem.

The fungus causing fusarium wilt affects only the cultivated tomato and certain wild tomato species. It enters through the roots and passes upward into the stem, where toxic substances that cause the wilting of the foliage and the eventual death of the plant are produced. In severely affected plants the fungus may pass into the fruits and may penetrate the seed. However, infection from internally infected seed is rare, as infected fruits usually decay and drop. When they are harvested, their seed are usually so light that they are eliminated in the extraction and cleaning of the seed. Spores may occur on the surface of the seed; but, if a surface disinfectant is used, there is little possibility of infection from this source. Nearly all infection can be traced to the presence of the organism in the soil. The fungus is most active at temperatures between 80° and 90° F. and is likely to be most damaging on light, sandy soils. Where climatic conditions are favorable to its growth, it can live almost indefinitely in the soil even when no tomatoes are grown. Previously clean fields may be infested by the planting of infected seedlings or by drainage water, farm implements, or any other agency that carries small amounts of infested soil.

Recommendations for Control

Seedlings should always be grown in clean soil, since wilt-free fields may become contaminated by the use of infected transplants. Seedbeds should not be located on old garden soils or on land where wilt is known to have occurred. If plants are purchased, they should be obtained from growers whose fields are free from wilt. Tomatoes

should not be grown on the same land more than once in 4 years if it can be avoided; a slight wilt infestation can soon be greatly increased by too frequent cropping with tomatoes.

When the disease has occurred in the greenhouse or hotbeds, the soil should be sterilized by steaming (p. 71) or treated with a chemical disinfectant such as formaldehyde (p. 72) or chloropicrin (p. 73). Chemicals can also be used for treating seedbeds where the disease has occurred, but the expense of treatment usually prohibits such treatment of field soils.

If tomatoes are grown where fusarium wilt is generally prevalent in the field, the best means of control is the use of resistant varieties. A considerable number of such varieties have been developed by the United States Department of Agriculture and various State experiment stations for use in both the field and the greenhouse. These varieties are not immune to fusarium wilt, and occasionally the plants may be damaged by the disease, but under most conditions they will produce satisfactory crops in fields where susceptible varieties are so badly damaged by wilt that little fruit is produced.

Among the resistant varieties in most general use in the field are Marglobe, Pritchard, and Rutgers. Marglobe is a main-crop tomato that is used for market and canning. Pritchard is a somewhat earlier variety used for market and early canning. Rutgers, a main-crop tomato, is extensively used for canning and also for market. Recently, the United States Department of Agriculture introduced Pan America, a red-fruited variety of the Marglobe type, which possesses extremely high resistance to wilt. The list of wilt-resistant varieties for greenhouse use includes Blair Forcing and Michigan State Forcing, both of which have been developed for resistance to wilt. These vary in type, and one that is best suited to the grower's local conditions should be selected.

VERTICILLIUM WILT

Verticillium wilt, caused by *Verticillium albo-atrum* Reinke and Berthold, resembles fusarium wilt in symptoms, but, except in certain sections of Utah and California, it causes little general damage to tomatoes. Occasionally it is of minor local importance in the Middle Atlantic and New England States, but it is almost unknown in the South. At times it may cause losses of some importance in greenhouses.

The first symptom is yellowing of the older leaves, accompanied by a slight wilting of the tips of the shoots during the day. The older, yellowed leaves gradually wither and drop, and eventually the crown of the plant is defoliated. The leaves higher up the stem become dull looking, and the leaflets tend to curl upward at the margin. All branches are uniformly affected and have a tendency to be less erect than those of healthy plants. The plants usually live through the season but are somewhat stunted, and the fruits are small. In late stages of the disease, only the leaves near the tips of the branches remain alive. The loss of the lower leaves and the stunting of the later growth expose the fruit to the sun, and much of the crop is often lost because of sunscald (fig. 3). When the stem is cut lengthwise, the base shows a discoloration of the woody tissues much like that caused by fusarium wilt. At times the discoloration is darker than that

caused by fusarium wilt, and generally it occurs only in the lower part of the stem. No soft decay of the stem and no spotting of the fruit are present.

Fusarium and verticillium wilts may occur in the same field and at times are hard to distinguish. Typical cases of fusarium wilt can be distinguished by the facts that single branches are often attacked and the plants more frequently wilt and die before the end of the season.

The fungus causing verticillium wilt is only rarely carried on the seed; but, as it can live for long periods in the soil, infection generally results from the presence of the organism in the soil. It attacks tomatoes, peppers, eggplants, potatoes, and a great number of other herbaceous and woody plants. The organism enters the plant through the roots and invades the water-conducting tissues of the stem. It is favored by temperatures of 70° to 75° F., and its progress is retarded by the higher temperatures that are most favorable to fusarium wilt.

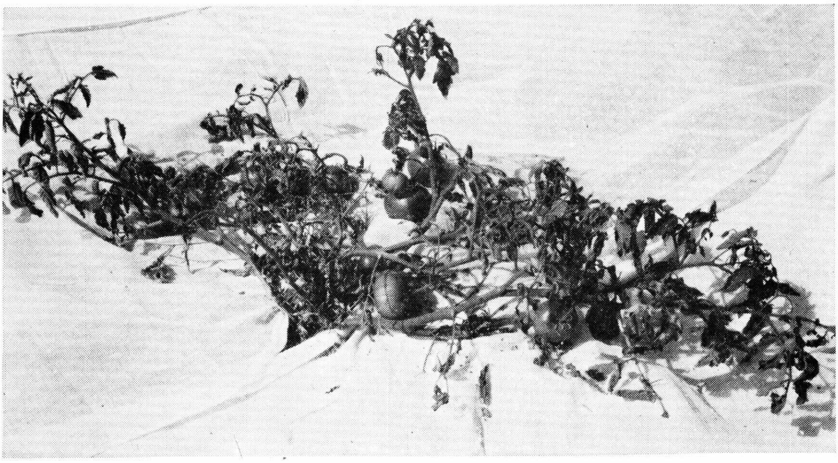

FIGURE 3.—Tomato plant affected with verticillium wilt. Note that the branches tend to lie close to the ground and the crown of the plant is open to the sun.

Recommendations for Control

Seed from plants affected by verticillium wilt should never be saved, to avoid the possibility of the fungus being carried on the seed. If it can be avoided, tomatoes should not be planted on land where the disease has previously occurred. If such land is used, 6 or 7 years should intervene between crops; peppers, eggplants, or potatoes should not be grown during this period. Tomato varieties developed for resistance to fusarium wilt are not resistant to verticillium wilt and cannot be depended on to prevent losses from this disease. Riverside and Essar, two varieties that possess some resistance to both verticillium and fusarium wilt, have recently been introduced jointly by the United States Department of Agriculture and the California Agricultural Experiment Station, but they are designed primarily for California conditions.

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Bacterial wilt, or brown rot, caused by *Bacterium solanacearum* E. F. Sm., is a disease that occurs most commonly on tomatoes in the Southern States but occasionally is also found in other tomato-growing regions. In the South the disease causes considerable injury to potatoes, tobacco, and peppers and also attacks peanuts, eggplants, soybeans, and a number of other cultivated and wild plants. It is not generally serious on tomatoes but causes some damage in occasional fields.

The symptoms are rather rapid wilting and death of the entire plant unaccompanied by any yellowing or spotting of the leaves (fig. 4).

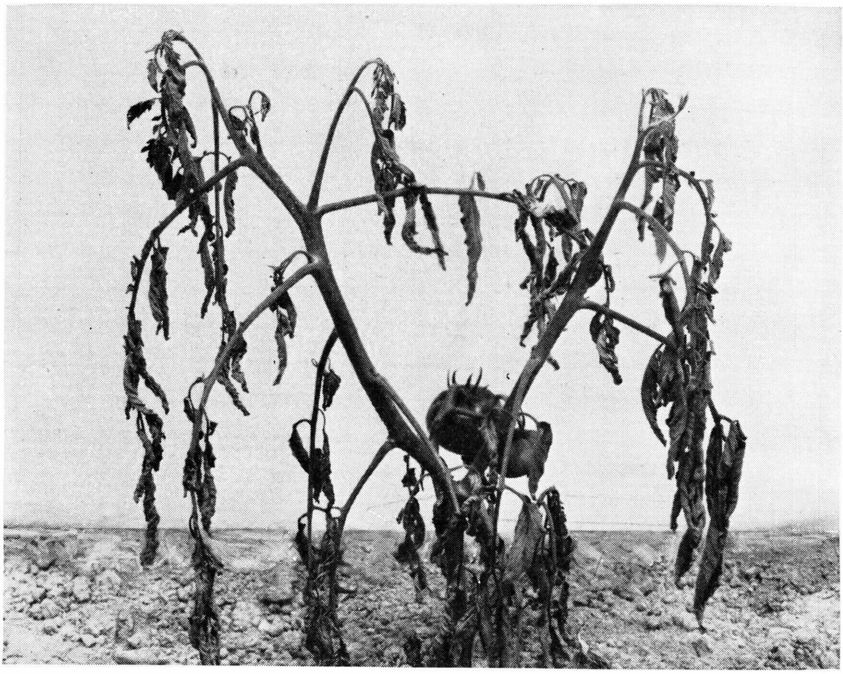

FIGURE 4.—Tomato plant showing symptoms of bacterial wilt. Note that all the branches have wilted at about the same time because of bacterial infection in the stem.

If the stem of a wilted plant is cut across near the ground line, the pith shows a darkened, water-soaked appearance and a grayish, slimy exudate is noted when the stem is pressed. In later stages of the disease there is a decay of the pith that may cause extensive hollowing of the stem (fig. 5). These symptoms differ from those of fusarium and verticillium wilts, which do not cause sudden wilting or decay of the stems of older plants. Bacterial wilt causes no spotting of the fruits.

The bacteria causing the disease live in the soil and infect the plant through the roots or stem. They are most common in low, moist soils and are most active at temperatures above 75° F. The bacteria may occur in newly cleared land as well as in that which has previously

grown susceptible crops. The disease is usually worst on light soils. Fields frequently are first infested as a result of planting infected seedlings, which often show no evidence of the disease until they are transferred to the field. The bacteria also may be carried by drainage water from an adjacent field.

FIGURE 5.—Split stems of tomato plants showing the discoloration and soft decay of the pith that occur in plants affected with bacterial wilt. The decay is accompanied by a rapid wilting of the tops.

Recommendations for Control

When the disease occurs, tomatoes should not be planted again for 4 or 5 years; such crops as tobacco, potato, eggplant, or pepper should not be grown during this interval. Care should be taken that seedlings are not grown on infested soil or on land in the immediate vicinity of infested fields. If a few wilted plants are noted in the field, they should be removed at once and destroyed to prevent further spread of the disease. If this is done, no replanting should be made at the point from which they were removed. All tomato varieties appear to be susceptible to bacterial wilt.

BACTERIAL CANKER

Bacterial canker is a destructive disease of tomatoes caused by *Corynebacterium michiganense* (E. F. Sm.) Jensen, a bacterium that may be carried by the seed. Because of this seed transmission of the causal bacterium, the disease has appeared at times in many of the major tomato-growing regions. In the past it has often caused serious losses, particularly on canning crops, but in recent years these losses have been much reduced by the greater care used in the production of seed free from the canker organism. The disease is occasionally found in the greenhouse, as well as in the field, and attacks plants at any stage of growth.

Frequently seedlings are infected; they may be rapidly destroyed or may produce plants that remain stunted and valueless. Occasionally, however, they may show no evidence of the disease until some time after being transplanted in the field. On older plants the first symptom is wilting of the margins of the leaflets of the lower leaves. This wilting usually appears first on the leaflets on only one side of the leaf; as the margins dry, the leaflets curl upward. Later these leaves become brown, wither, and die, but the petioles remain attached to

the stem (fig. 6). The plant itself often shows a one-sided development of the disease, which causes it to lie over in a characteristic fashion. On larger plants a single shoot may be killed early, and the remainder of the plant may appear normal for some time; but eventually the entire plant is affected. The dying continues up the stem, and much of the foliage is destroyed.

The bacteria attack the softer tissues just within the bark or cortex of the stem, and the pith is then easily separated from the woody portion of the stem. As the decay progresses, the pith becomes yellow and mealy in appearance and cavities form within the stem. Later the destruction of the tissues extends to the outer surface of the stem, and open cankers, which give the disease its name, are formed (fig. 7). Diseased plants may die early, but they often survive until harvest.

Often the fruits are infected on the surface, where the symptoms appear first as small, raised, snowy-white spots, one-eighth to one-fourth inch in diameter. The centers of these spots later break open and become brown and roughened; the white color persists as a halo about the margin and produces the bird's-eye spot typical of the

FIGURE 6.—Tomato plant attacked by bacterial canker. Many of the leaflets are curled and withered, but the petioles remain attached to the stem.

disease (fig. 8). These spots caused by rain washing the bacteria from open cankers to the fruit do not extend deeply into the flesh. When the plants are severely diseased, the fruits may also be internally infected. If this occurs when the fruits are small, they are stunted and deformed. Internally infected fruits often show no external evi-

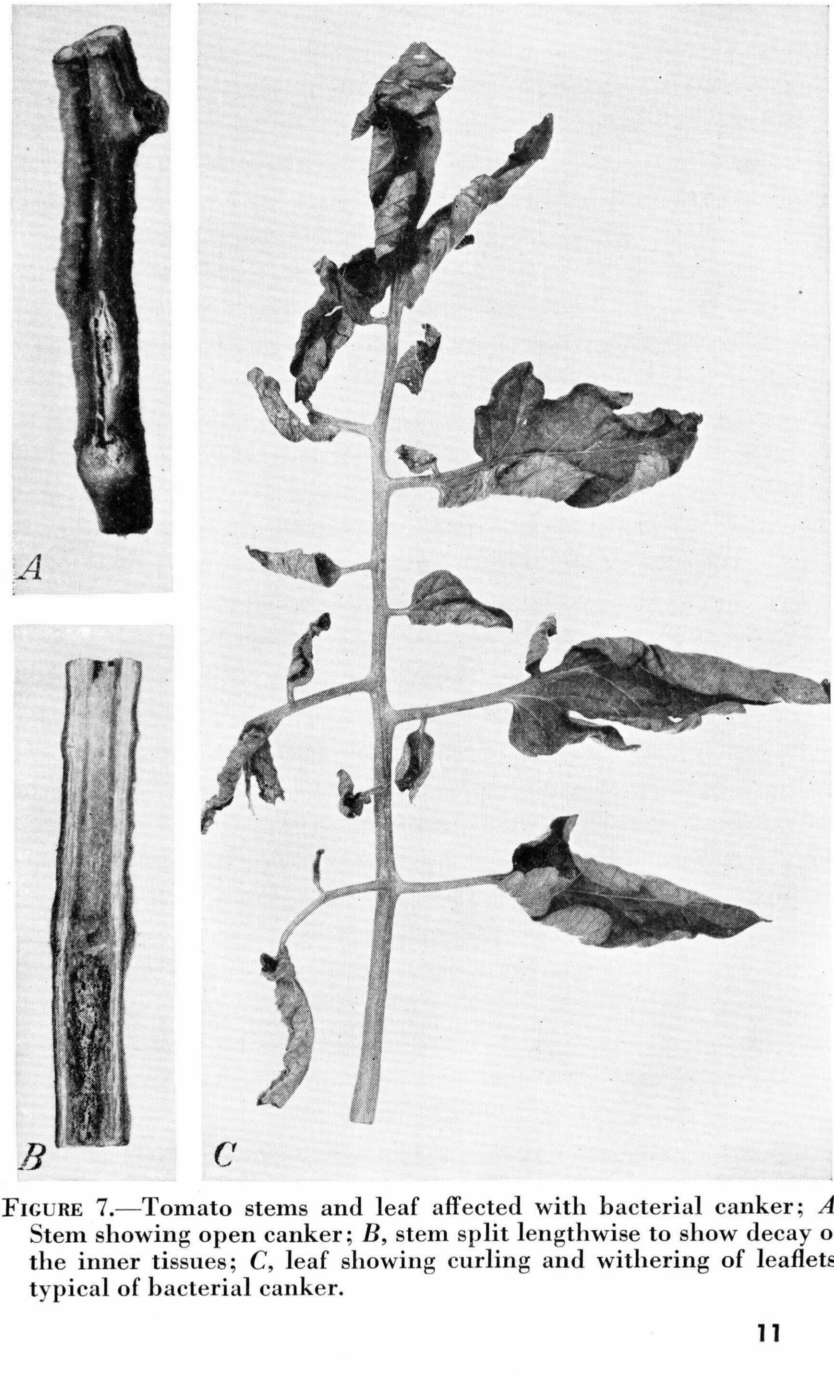

FIGURE 7.—Tomato stems and leaf affected with bacterial canker; *A*, Stem showing open canker; *B*, stem split lengthwise to show decay of the inner tissues; *C*, leaf showing curling and withering of leaflets, typical of bacterial canker.

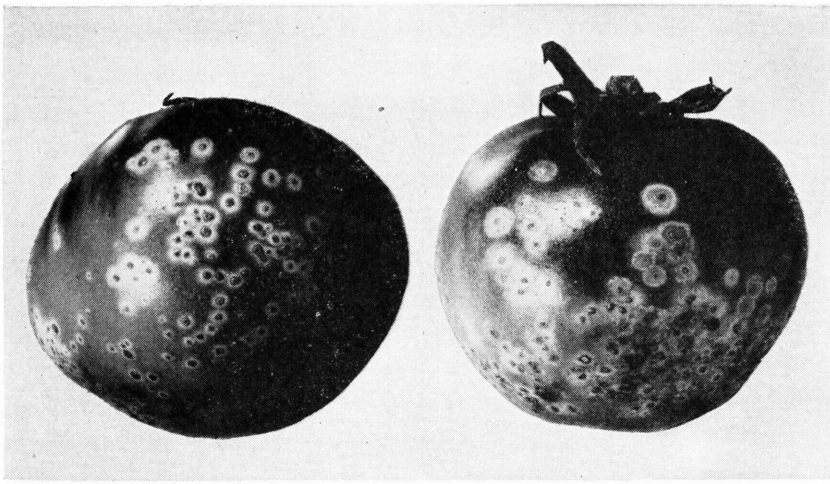

FIGURE 8.—Tomatoes showing the bird's-eye spotting caused by the bacterial canker organism. The spots have dark, roughened centers and light, halolike margins.

dence of the disease, but small cavities may be found in the central portions of the fruits. When such infection occurs, the bacteria may become lodged in the tissues that become part of the seed. If this occurs early in the development of a seed, it is destroyed, but if the invasion occurs after the ovule is well developed, a viable seed that carries the canker bacteria may be produced.

Most of the serious outbreaks of bacterial canker in the field can be traced to contaminated seed or soil. Internally infected seed is responsible for some infection, but this is probably less common than that resulting from the presence of the organism on the surface of the seed. This surface contamination occurs when seed is extracted from fruits harvested from fields where the disease occurs and, when once lodged on the surface of the seed, a certain percentage of the bacteria are able to survive until the following season. The bacteria can live for at least 2 years in the soil; infection is often caused by bacteria in seedbed soils.

Recommendations for Control

Bacterial canker is unlikely to occur if clean seed is planted in clean soil. Every effort should be made to obtain seed from canker-free fields, since it is much safer to use seed free from the canker organism than to depend on even the most efficient seed treatment. Several States now maintain an inspection service through which seed-producing fields of the more widely planted tomato varieties are inspected throughout the season for the presence of bacterial canker and certain other diseases. Seed meeting the requirements as to freedom from these diseases is given State certification. The use of such seed is a valuable means of avoiding losses from bacterial canker.

At times, however, it may be necessary to use seed whose history as to bacterial canker is uncertain. Special seed-stock plantings also may become infected, and clean seed of the same stock may not be available. Under such circumstances it is essential that the seed be treated to free it from the canker organism.

It has been found that seed of contaminated fruits can be freed from the canker bacteria by fermenting the crushed fruit pulp for 96 hours before extracting the seed. The fruits should be thoroughly pulped before being allowed to ferment and, if it is possible to do so, it is well to run the fruits through some form of tomato juicer and then to recombine the juice, pulp, and seed for fermenting. Water should never be used in place of tomato juice in this process, as this reduces the effectiveness of the treatment. It is essential that the fermenting pulp be kept at an even temperature not much above or below 70° F. Higher temperatures increase the chemical activity of the fermenting pulp and may injure the vitality of the seed. The fermenting material should be stirred twice a day to submerge the pulp floating on the surface.

When seed is extracted mechanically without fermentation it may be treated before drying by being soaked in an 0.8-percent solution of pure (U.S.P. grade) acetic acid in water. A solution closely approximating an 0.8-percent solution is prepared by adding 1 fluid ounce of acetic acid to 1 gallon of water. The seed is placed in a loosely woven cloth bag and immersed in the solution for 24 hours at an even temperature not much above or below 70° F. The solution must be thoroughly stirred to insure the wetting of all the seed. Only 1 pound of seed should be treated in 1 gallon of the solution. Dried seed may be treated in a 0.6-percent solution of acetic acid. A solution closely approximating this is prepared by adding three-fourths of an ounce of acetic acid to 1 gallon of water. The same precautions as to temperature must be used as with freshly extracted seed. Immediately after treatment the seed is dried at a moderate rate.

These treatments cause a slight reduction in germination, but this is negligible if the directions about temperature are carefully followed. The fermentation and acid-soak treatments have proved very effective in the prevention of bacterial canker infection and appear to kill both surface-carried bacteria and many within the seed.

Another method that is effective in destroying bacteria within the seed consists in treating the seed with water heated to a temperature that will destroy the parasite but will not seriously injure the vitality of the seed. This method (p. 69) requires careful handling but is very effective in freeing the seed from the bacterial canker organism.

Even where the seed used is known to have come from fields apparently free from bacterial canker, it is best to treat it with bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67) as a precaution against contamination by any of the disease-producing organisms that are likely to occur on the seed. These treatments, however, are effective only against organisms on the surface of the seed.

Although much bacterial canker infection can be traced to the seed, the bacteria also may live for at least 2 years in the soil, and seedbeds should not be planted on the same soil more than once in 5 years. Beds should not be located on soil that is likely to be contaminated by drainage from fields recently planted to tomatoes.

When hotbed or coldframe soils are infested, such soils should be replaced to a depth of 10 inches with soil that has not grown tomatoes. The frames and covers should be disinfected by drenching with a 1 to 30 solution of commercial (40-percent) formaldehyde, and before the new soil is placed in the bed the subsoil also should be drenched with the same solution. This should be done at least 3 weeks before plant-

ing. If the soil cannot be changed, it must be disinfected with steam (p. 71) or with formaldehyde (p. 72) or chloropicrin (p. 73).

A 5-year rotation will avoid infection in the field, since the canker organism is not known to persist for more than 3 years in the soil. In the greenhouse, soil sterilization is necessary if the disease has appeared on the preceding crop.

SOUTHERN BLIGHT

The disease known as southern blight, or sclerotium rot, is caused by *Sclerotium rolfsii* Sacc., a fungus that occurs to some extent throughout the southern United States but is comparatively rare in other tomato-growing regions. It attacks a number of plants other than tomatoes, including vegetables such as beans, cabbage, sweet-potatoes, beets, eggplants, peppers, squash, watermelons, and potatoes. Various other crops and ornamental plants are also attacked. On tomatoes the disease is not of major importance but occasionally causes some loss.

The first symptom on tomatoes is a general drooping of the leaves suggestive of bacterial or fusarium wilt. Wilting becomes more marked from day to day, and finally the plant dies without marked yellowing of the foliage. The stems of these plants show a brown decay of the outer tissues at the ground line. Frequently they are covered with a white fungus mat in which are embedded numerous small, light-brown bodies about the size of a cabbage or mustard seed (fig. 9). These are known as sclerotia and are a distinguishing feature of the disease.

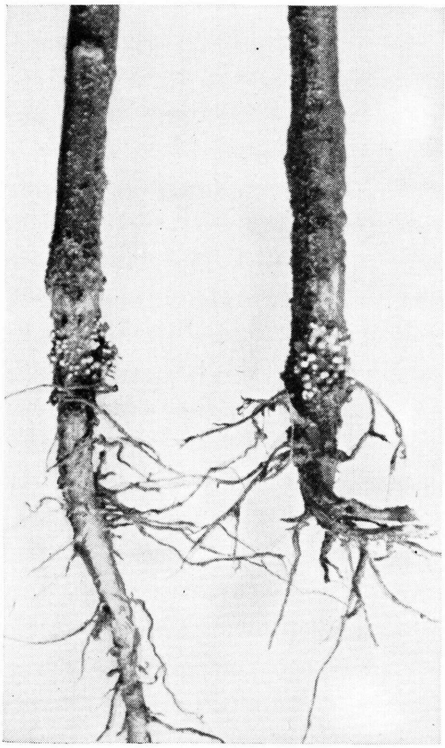

FIGURE 9.—Roots and stems of tomato plants attacked by southern blight. Note the small, light-brown sclerotia of the causal fungus on the stems. These are characteristic of the disease.

The fungus also attacks the fruits where they touch the soil, producing yellowed, slightly sunken areas that break open as the spots enlarge. The progress of the decay is rapid; the fruit soon collapses and is covered by a growth of the fungus.

The fungus makes little growth at temperatures below 68° F. and is, therefore, largely confined to the South. It requires abundant moisture for growth and is most prevalent on light, poorly drained soils. Apparently it produces no spores, but the threads of the fungus spread through the soil and the infested areas

widen from year to year. It is also distributed by means of the sclerotia, which can live for some time in the soil and are spread by washing rains or during cultivation. Under favorable conditions these sclerotial bodies are able to put out new fungus threads and to cause further infection.

Recommendations for Control

Sanitation is important in the control of southern blight. Where only an occasional infected plant is found, it should be removed and burned. This is particularly important in small plantings, where all the plants can be readily observed for the presence of the disease. Rotation is important, and fields in which the disease has been prevalent should not be planted to tomatoes or other susceptible crops for at least four seasons. Care should be taken not to locate seedbeds on land where the disease has occurred.

STEM ROT

Stem rot, or timber rot, is a minor disease of tomatoes that is usually more common in the greenhouse than in the field. It is caused by *Sclerotinia sclerotiorum* (Lib.) DBy., a fungus that frequently causes losses on cabbage, celery, lettuce, carrots, beans, spinach, eggplants, cucumbers, onions, beets, and several vegetable crops. Tomatoes are rarely affected unless grown in soil where the disease has been severe on other crops, and generally only an occasional field is badly damaged. In the field the disease is most common in the South Central and South Atlantic States.

The fungus attacks the stem at the ground line and causes a decay of the soft, inner tissues that results in

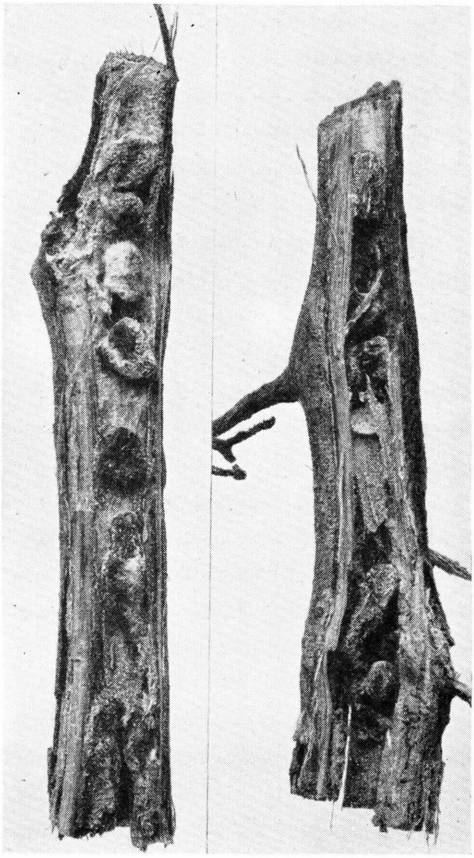

FIGURE 10.—Stems of tomato plants killed by stem rot. Note that the fungus has destroyed the inner tissues of the stems and the cavities contain the large sclerotia formed by the fungus. These are darker and much larger than the sclerotia of the fungus causing southern blight.

slow wilting and eventual death of the plant. In late stages of the disease, the surface of the stem is often covered by a white growth of the fungus mycelium. If the stem is broken open it will commonly be found to contain cavities filled with grayish-white fungus growth, in which are embedded the black, hard sclerotia characteristic of this organism. They are larger (one-fourth inch in length) and more irregular in shape than those of the southern blight fungus and are not generally found on the surface of the stem (fig. 10). These sclerotia are resistant to unfavorable environmental conditions and serve to maintain the fungus in the soil from season to season. When moisture and temperature conditions are favorable, the sclerotia produce small, delicate, cup-shaped bodies, in which fungus spores are produced. Occasionally this fungus causes a watery, soft rot of the fruit.

Recommendations for Control

Stem rot usually occurs only under conditions of high humidity and on moist soils. Temperatures between 60° and 75° F. are conducive to infection by the fungus. Tomatoes in well-drained fields are not likely to be damaged unless grown immediately after diseased crops such as celery, beans, or lettuce. Serious damage in the greenhouse can be prevented by steam sterilization of the soil (p. 71).

DAMPING-OFF

Tomato seedlings are particularly susceptible to the disease known as damping-off; and, where measures have not been taken for its control, the grower often finds that great numbers of seedlings have collapsed and died almost overnight. This trouble is caused by the attacks of various fungi that are commonly present in the soil. Most of the damping-off of tomatoes is apparently due to certain species of *Pythium*, but some damage also results from infection by *Rhizoctonia solani* Kühn; at times other fungi also cause injury of this type. The disease occurs on seedlings in the field as well as in the greenhouse and hotbed plantings. It is not confined to any particular region.

The injury from damping-off is of two types. One of these, known as preemergence damping-off, is an attack by the damping-off fungi which causes a decay of the seed or kills the seedling before it can push through the soil. This injury to the germinating seeds is very common and frequently is the cause of poor stands, which are likely to be attributed to inferior quality in the seed.

The other type of the disease, known as postemergence damping-off, is the one ordinarily associated with the words "damping-off." It occurs after the seedlings have emerged from the soil but while they are still small and tender. The roots may be killed, and affected plants show water soaking and shriveling of the stems at the ground line (fig. 11) and soon fall over and die. Damping-off usually occurs in small patches at various points in the seedbeds; these spots often increase in size from day to day until the seedlings reach such a size that they are no longer susceptible to attack. Seedlings are extremely susceptible to damping-off for 2 to 3 weeks after they emerge, but as the stem hardens and increases in size, the injury no longer occurs. Often the seedlings are not killed at once, but the roots are severely damaged and the stem is girdled at the ground line. Such plants remain stunted and often do not survive transplanting.

The fungi causing damping-off are most active in moist soil; excessive soil moisture is commonly associated with severe injury from this disease, but some losses may occur where soils are only moderately moist. Seedlings should not be grown in poorly drained seedbeds or fields. Care should also be taken not to overwater plants in hotbeds, particularly during cool, wet weather. If the plants are grown in the greenhouse or in sash-covered frames, it is essential that they be given good ventilation in order to keep the humidity low.

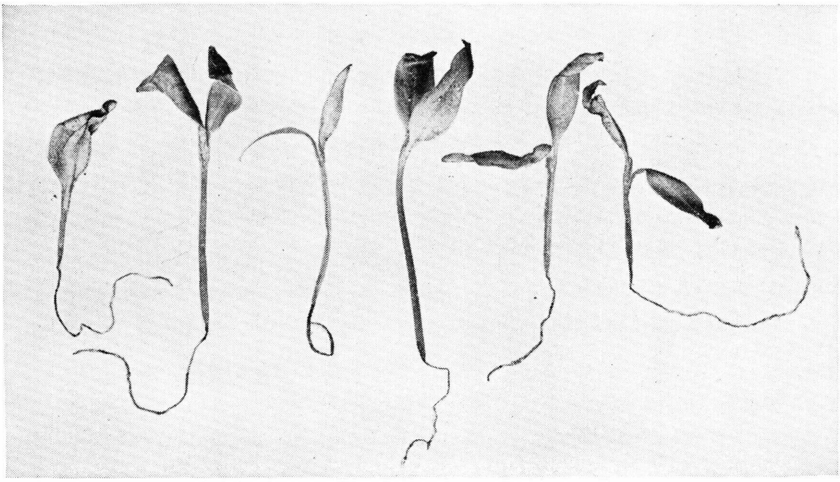

FIGURE 11.—Tomato seedlings affected with damping-off. Note that the stems are shriveled at the ground line and the roots are killed.

When damping-off fungi are known to be present in the soil, it is possible to rid the soil of them by steam (p. 71) or chemical (p. 72) treatments. Where small quantities of soil are to be treated for use in flats, the concentrated formaldehyde solution described on page 73 is very effective. Such treatments do not, however, prevent the recontamination of the soil with damping-off fungi, and the disease may later reappear.

Soil sterilization is expensive and time-consuming, and its use in the control of damping-off can usually be avoided by treating the seed with one of the protective fungicides described on pages 69 and 70. These treatments coat the seed with a chemical that tends to prevent soil organisms from causing decay of the seed and preemergence damping-off. They may vary in effectiveness under certain unusual soil or environmental conditions, but all have given good results.

EARLY BLIGHT

Early blight, caused by *Alternaria solani* (Ell. and G. Martin) Sor.,[3] occurs to some extent in most tomato-growing regions and is one of the most common and serious diseases of this crop in the New England, Atlantic, and Central States. It is of comparatively minor importance in the Pacific Coast States, but occasionally there are local

[3] Formerly known as *Macrosporium solani* Ell. and G. Martin.

losses where conditions favor its development. The fungus causes a stem canker or collar rot that is very damaging to young seedlings and transplants in the field and produces a spotting of the leaves that may partially defoliate the plants and greatly reduce the size and quality of the crop. The fruits also are attacked and may drop before they mature or may develop dark, decayed spots as they ripen.

In the field the first symptoms of early blight usually appear on the older leaves and consist of small, irregular, brown, dead spots. The spots enlarge until they are one-fourth to one-half inch in diameter; as they enlarge, they commonly show ridged, concentric rings in a target pattern (fig. 12, *A*). In the field some spotting of the leaves ordinarily may be found early in the season, but the greatest leaf injury usually appears after the fruit is well set. If high temperatures and humidity occur at this time, much of the foliage frequently is killed by the latter part of the season and the vines are badly defoliated.

On the stem, early blight causes small, dark, slightly sunken areas that enlarge to form circular or elongated spots with light centers, which occasionally show concentric markings like those on the leaves (fig. 12, *B*). Large spots often appear on the stems of seedlings at the ground line, causing the partial girdling known as collar rot (fig. 12, *C*). When set in the field, such plants die or the stem is so weakened that it breaks over early in the season, thus forcing the plant to depend on a reduced root system developed where the portion of the stem

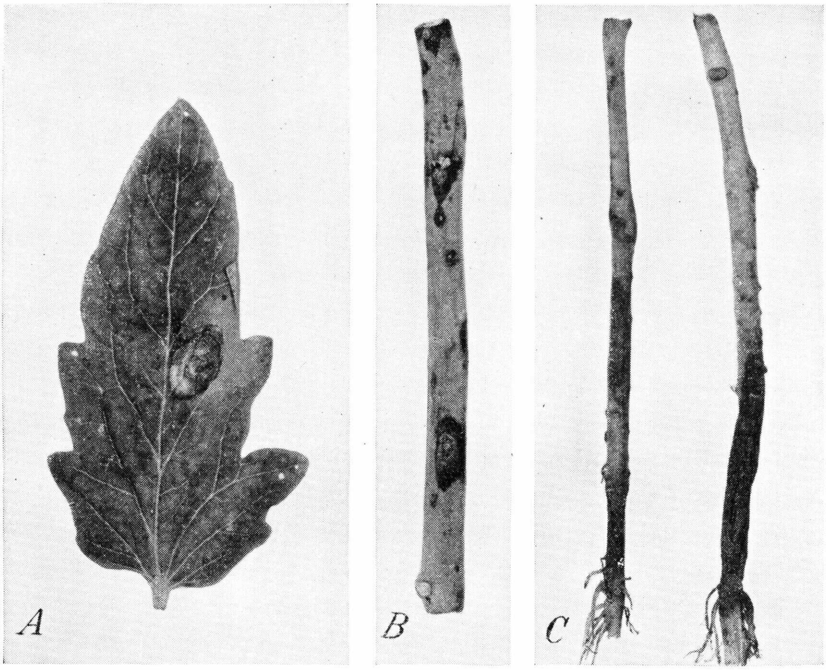

Figure 12.—Leaflet and stems of tomato showing symptoms of early blight: *A*, Leaflet showing a spot with characteristic targetlike markings and yellowing; *B*, cankers on stem of an older plant; *C*, collar rot injury on seedling stems.

above the canker is in contact with the soil. Such plants remain small and produce few fruits. On older plants the stem cankers that occur later in the season are most numerous on the lower portions of the shoots. They are usually light brown at the center, with darker margins, and may be so numerous as to almost cover the stem.

Early blight also causes spotting of the fruit stems and may cause some blossom drop and loss of young fruits. On older fruits it causes dark, leathery, sunken spots at the points of attachment to the stems. These spots reach a considerable size and may show concentric markings like those on the leaf (fig. 13). The dark, dry decay extends to

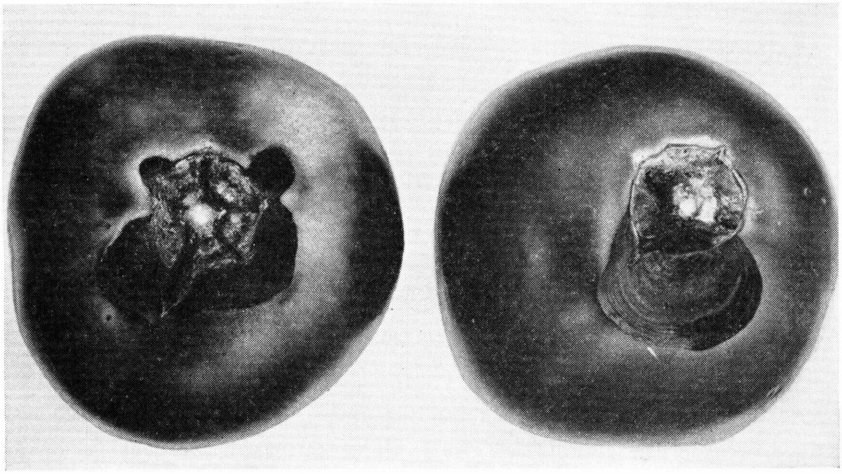

FIGURE 13.—Tomatoes showing symptoms of early blight. Infection usually takes place near the stem scar, and the spots show concentric markings.

some depth into the flesh of the fruit. Infected fruits frequently drop and, if they reach maturity, are not fit for market or canning.

The fungus that causes early blight of tomatoes also causes early blight of potatoes. It attacks eggplants and also horsenettle, nightshade, and certain other wild plants related to the tomato. The fungus may occur on or in the seed, but internal infection is rare in seed produced commercially, since seed is commonly obtained from tomatoes used for manufactured products and badly infected fruits are discarded in the manufacturing process. The organism can live on decayed plant tissue in the soil and is widely distributed in regions where climatic conditions favor the development of early blight in the field. Primary seedling infection probably is most often due to the fungus in the soil and occurs most abundantly during periods of rain or extremely humid weather when the air temperatures are above 75° F. Crowding of plants in the seedbed favors the rapid spread of the disease, and poorly nourished plants seem most susceptible. In the field the spores produced in the spots on the leaves and stems are spread by wind, rain, or human beings to adjacent plants, and when climatic conditions favor infection, the disease soon becomes general. Plants carrying a heavy load of fruit appear to be more susceptible than those in an earlier stage of growth.

Recommendations for Control

The prevention of seedling infection is very important in the control of early blight. The seed should be treated with bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67) as a protection against surface contamination and should not be planted on soils where the disease is known to have occurred. If permanent beds are used, the soil should be replaced or disinfected by treatment with steam (p. 71) or a chemical disinfectant (p. 72). Where plants are grown in hotbeds or coldframes ample ventilation should be provided, and all watering should be done in the morning on a fair day, to insure rapid drying of the leaves. Plant beds containing numbers of plants showing collar rot, stem cankers, or leaf spotting are best abandoned entirely, since further stem infection is likely to develop after transplanting to the field. If plants are purchased, they should not be taken from shipments in which many of the plants show infection. Plants should not be held in the beds for long periods after they reach transplanting size; crowding increases the danger of infection. Seedlings can be protected by spraying at 7- to 10-day intervals with fixed copper fungicides (p. 76); these should be used at the same strength (2 pounds of actual copper to 100 gallons) recommended for plants in the field. Bordeaux mixture (p. 77) may injure seedlings and should never be used just before they are to be transplanted.

Copper fungicides have been generally used for control of early blight of tomatoes in the field; but recent work indicates that a new organic fungicide, zinc dimethyl dithiocarbamate (p. 77), is about as effective against this disease and gives better control of anthracnose (p. 28) and leaf mold (p. 25). If copper fungicides are used, the fixed copper compounds (p. 76) are preferable to bordeaux mixture because they are less likely to injure the foliage. The first application of a fungicide should be made about 30 days after the first cluster blooms. Later applications of sprays should follow at 10-day intervals and of dusts at 7-day intervals. When rain is frequent these intervals should be shortened. In prolonged dry weather the time between applications may be lengthened, but it must be remembered that leaf infections can develop rapidly if plants are left unprotected by a fungicide during a sudden onset of prolonged wet weather.

Leaves and fruit of the tomato varieties in common use have not shown marked resistance to early blight infection. Some foreign varieties show resistance to collar rot; and the varieties Norduke, Riverside, and Prairiana also have considerable resistance to stem infection. Breeding for resistance to leaf infection is receiving much attention at present.

NAILHEAD SPOT

Prior to 1926 the disease of tomato fruits known as nailhead spot, caused by *Alternaria tomato* (Cke.) Weber,[4] was one of the most serious diseases affecting the tomato crop in Florida and was the cause of some losses in other of the South Atlantic States and in the South Central States. Since that time the widespread use of Marglobe and other varieties whose fruits are resistant to infection has so reduced the injury from this disease that it is now comparatively unimportant.

In both the seedbed and the field the symptoms of nailhead spot on the leaves and stems are almost identical with those of early blight

[4] Formerly known as *Macrosporium tomato* Cke.

(p. 17), which is caused by a closely related fungus. On the fruits, however, the nailhead spotting is quite unlike that caused by early blight. Fruits may be infected by the nailhead spot organism at any stage of their growth and on any part. The first symptoms are minute tan spots that enlarge until they are one-sixteenth to three-eighths inch in diameter. At this stage the centers of the spots are slightly sunken, and the margins are darker, but as the spots become older the centers are more definitely sunken and become grayish brown, with the surfaces roughened by the drying and tearing-back of the epidermis (fig. 14 and cover). When very numerous, the spots coalesce and often cause irregularities in the shape of fruits infected when small. In ripening fruits the tissues immediately around the spots often remain green in color. The fungus ordinarily does not penetrate deeply into the fruit, but secondary infections with other organisms sometimes result in serious decay. Fruits infected but showing no symptoms when packed may develop spots in transit and storage.

The nailhead spot fungus is very similar to that causing early blight, and their life histories are almost the same. Warm, rainy weather is most conducive to infection and rapid development of the disease on the foliage and fruits. Spores are produced on the surface of the spots on the fruits, leaves, and stems. These spores are spread by wind and splashing rains. Seedling infection often can be traced to the presence of the organism in seedbed soils.

Recommendations for Control

The recommendations for seedbed sanitation, seed treatments, and spraying, as given for early blight (p. 20), also apply to the control of nailhead spot. However, the most effective means of preventing losses from fruit infection consists in the use of varieties whose fruit

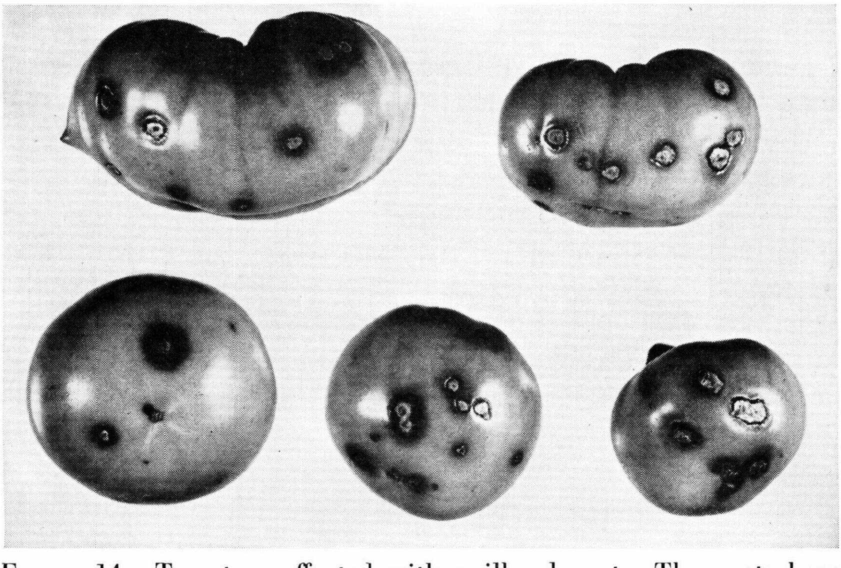

FIGURE 14.—Tomatoes affected with nailhead spot. The spots have grayish-brown centers and darker margins; their surfaces have a roughened, torn appearance.

is resistant to attack by the nailhead spot fungus. No variety now in use is particularly resistant to the leaf and stem injury, but several varieties developed by the United States Department of Agriculture produce fruits resistant to nailhead spot. These varieties are the Marglobe, Pritchard, Glovel,[5] and Break o' Day, all of which are also resistant to fusarium wilt (p. 4). Marglobe is a midseason, widely used, red tomato, and Pritchard is a somewhat earlier red variety of excellent quality. Glovel is a pink-fruited shipping variety, and Break o' Day is an early red-fruited variety that does best under cool conditions. The fruits of these varieties remain relatively free from nailhead spot when susceptible varieties are severely damaged.

SEPTORIA LEAF SPOT

Septoria leaf spot, or septoria blight, caused by *Septoria lycopersici* Speg., is one of the most damaging of the tomato leaf diseases and often causes severe losses in the Atlantic and Central States. It occurs rather frequently as far south as Arkansas, Tennessee, and South Carolina, but it is of minor importance in the more southern States and in the Mountain and Pacific coast regions. In seasons when temperatures are moderate and rainfall is abundant, the disease often destroys so much of the foliage that the plants fail to mature their fruits properly and there is considerable injury from sunscald.

The disease may occur on plants of any age, but in the field it usually becomes most evident after the plants have begun to set their fruit. The first infection ordinarily is found on the older leaves near the ground, and the early symptoms are small, water-soaked spots that often are scattered thickly over the leaf. These spots soon become roughly circular and have gray centers surrounded by darker margins. Later the centers show tiny dark specks in which the spores of the fungus are produced (fig. 15). The spots are smaller and more numerous than those of early blight; usually they are one-sixteenth to one-eighth inch in diameter. If they are numerous, the leaflet eventually dies and drops from the plant. When conditions favor infection, there is a progressive loss of foliage until only a few leaves are left at the top of the stem, and the fruits are exposed to sunscald. The fruits are rarely affected, but there may be spotting of the stem and blossoms.

Septoria leaf spot is caused by a fungus that also attacks wild relatives of the tomato, such as jimsonweed, horsenettle, groundcherry, and nightshade. It overwinters on the remains of tomato plants or weed hosts or on other decaying vegetation. The first infection results from the spread of the spores produced on such material to the leaves of the tomato. After infection occurs numerous spores are produced in the dark specks formed in the leaf spots. During wet weather these spores are exuded onto the leaf and are splashed onto other leaves by rain or spread by brushing the moist foliage. The fungus is most active when temperatures range from 60° to 80° F. and rainfall is abundant. During hot, dry seasons it causes little damage.

Recommendations for Control

It has been found that this leaf spot fungus will not live over on the remains of plants buried deeply in the soil; deep plowing in the fall or early spring will do much to prevent infection, if all vines are covered. In small gardens the plants should be collected in the fall

[5] Developed in cooperation with the Florida Agricultural Experiment Station.

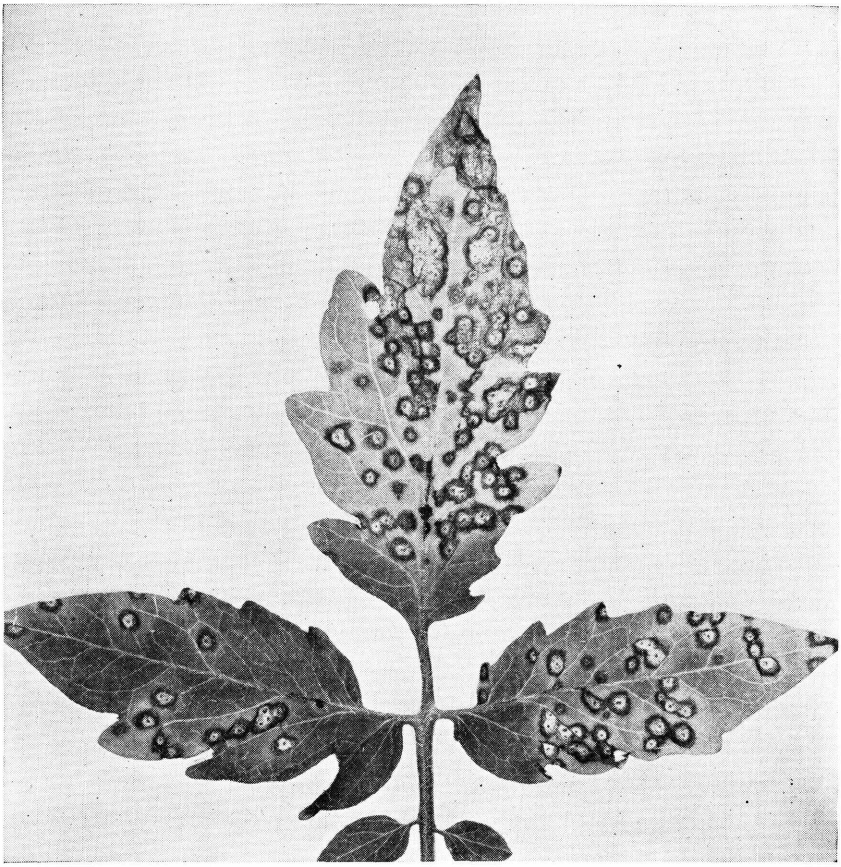

FIGURE 15.—Tomato leaflets affected with septoria leaf spot. Note the light centers and darker margins of the spots. From the dark specks in the centers of the spots masses of fungus spores are exuded in wet weather.

and burned. Since weeds harbor the fungus, clean cultivation and control of weeds are also important. Long rotations will help to free the fields of the fungus, particularly if legumes or cereals are grown. The disease can be controlled to some extent by spraying with one of the fixed copper compounds (p. 76) or bordeaux mixture (p. 77) or by use of copper dusts (p. 76). The organic compound zinc dimethyl dithiocarbamate is not as effective against *Septoria* as it is against the fungus causing early blight. Spraying or dusting must begin before the disease gains headway, and the materials must be properly applied. When conditions favor the septoria leaf spot and good yields may be expected if it is controlled, spraying or dusting should be profitable.

LEAF MOLD

Leaf mold, caused by *Cladosporium fulvum* Cke., is one of the most common and destructive diseases of greenhouse tomatoes. In some of the South Central and South Atlantic States the disease may be of considerable importance in the field in wet seasons, and occasionally

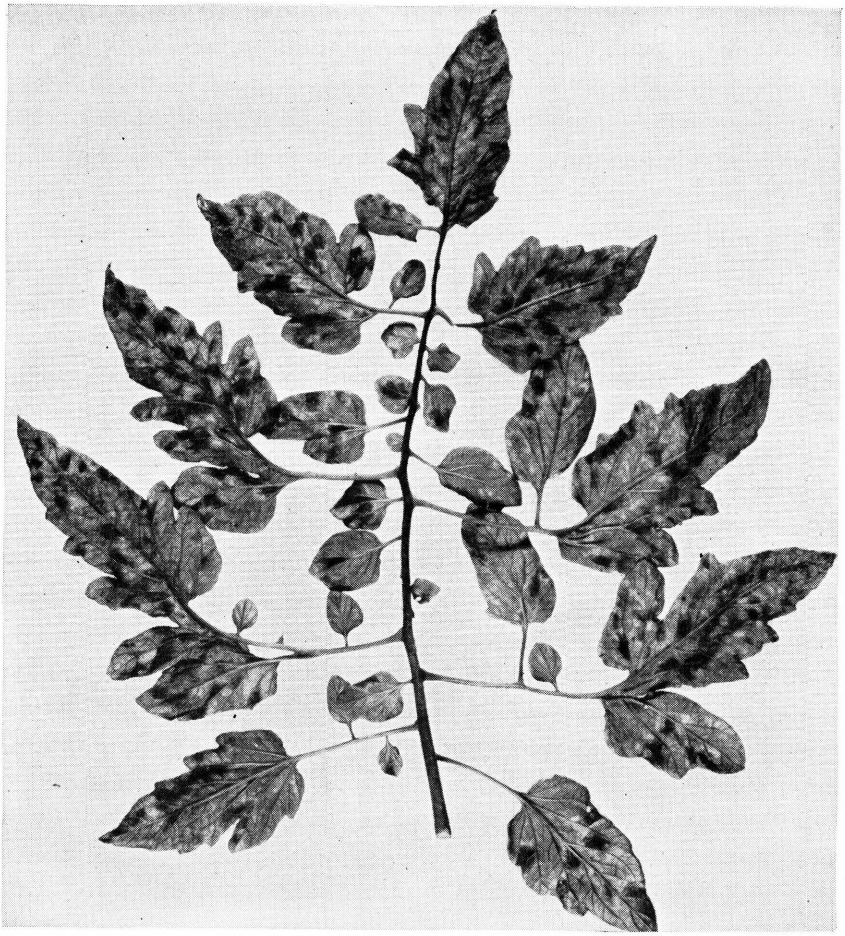

FIGURE 16.—Under side of a tomato leaf, showing dark patches of the leaf mold fungus. These patches are covered with spores, which are readily detached and spread to healthy foliage. (*Courtesy of the Ohio Agricultural Experiment Station.*)

it is serious in the East North Central and Middle Atlantic States. The first symptoms usually appear on the upper surfaces of the older leaves. These symptoms are diffuse whitish spots, which rapidly enlarge and become yellow. Under humid conditions the lower surfaces of these patches become covered with a velvety, olive-brown coating of the causal fungus (fig. 16). When conditions favor the development of the disease in the greenhouse, much of the foliage eventually is killed, and the crop is greatly reduced. The fruit stems and blossoms occasionally may also be infected, but fruit infection is rare.

The fungus spores are produced in great numbers on the undersurfaces of the leaves and are spread by air currents, watering, and contact with the plants. The spores are resistant to drying and may survive about the greenhouse for several months after the plants have been removed. Occasionally the spores may be carried on the seed.

Spore germination and leaf infection occur only when the relative humidity is high (90 to 100 percent) at the leaf surface. Therefore the fungus is most destructive when the humidity is high and temperatures range from 65° to 80° F. Such high relative humidity may occur at the leaf surface and immediately around the leaves when the relative humidity is considerably lower in the open parts of the greenhouse. The reason is that the leaf itself gives off some moisture, and there often is a condensation of moisture on the leaves from the air. Therefore, the disease is usually most destructive in the greenhouse from May to November, when the relative humidity is likely to be high and air temperatures are such that heating is not continuous. As the air temperatures drop after sundown, the relative humidity rises until it approaches saturation at the leaf surface (usually about midnight), and conditions are then favorable for infection.

Recommendations for Control

Spraying with the organic fungicide zinc dimethyl dithiocarbamate (p. 77) seems to give good control of leaf mold in the field. Copper compounds appear to be less effective but give some control. In the greenhouse such measures have not been very successful because of difficulty in covering the undersurfaces of the leaves. Leaf mold can often be checked, however, if there is ample ventilation and good air circulation in the houses. During the warmer spring and fall months, the ventilators should be handled to provide maximum ventilation, and sufficient heat should be provided to maintain temperatures of at least 60° to 65° F. If heat is provided at night, when the outside temperature drops below 60°, some of the increase in relative humidity that comes with a lowering of the air temperature can be avoided. In the Central States many growers use some heat at night until the first week in July, almost regardless of the outside temperatures. Also many of these growers commence night heating again during the latter part of August or early in September. The combination of heat and ventilation sets up currents of air that help to prevent an accumulation of moisture on the foliage. The disease usually will not be severe if the relative humidity is kept below 90 percent. Forced circulation of air by fans or blowers has been tried in some instances, but their installation is expensive and results have not been particularly satisfactory.

The best solution of the leaf mold problem in the greenhouse lies in the development of varieties resistant to the disease. Some such varieties are now available. A pink-fruited variety, Globelle, developed by the Ohio Agricultural Experiment Station, a red-fruited variety, Bay State, developed at the Massachusetts Agricultural Experiment Station, and a red-fruited variety, Vetomold, developed by the Ontario Agricultural Experiment Station, all have been introduced. These varieties are not resistant to all strains of the fungus, but they are likely to prove valuable as a means of reducing losses from the disease.

STEMPHYLIUM LEAF SPOT

Stemphylium, or gray, leaf spot, caused by *Stemphylium solani* Weber, is a fungus disease of the foliage and does not affect the fruit. It frequently causes serious losses in Florida and is found in South Carolina and Georgia, but it is seldom prevalent in sections farther north. The disease is most severe in warm, humid weather, and at

times it causes a severe defoliation of the plants in both the seedbed and the field. The first infection usually occurs on the older leaves, which show numerous small, dark-brown spots that extend through to the undersurface of the leaf. These spots generally remain small, but they may enlarge until they are one-eighth inch in diameter. As they enlarge, the spots develop a grayish-brown glazed appearance (fig. 17), and at times the centers crack and tear across. When the spots

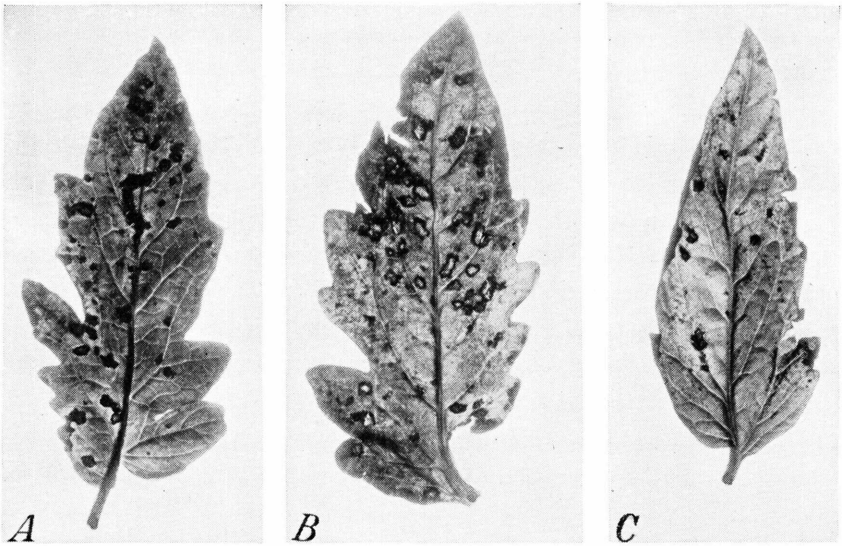

FIGURE 17.—Tomato leaflets affected with stemphylium leaf spot: *A*, Leaflet showing numerous small brown spots typical of the early stage of the disease; B, leaflet showing light-colored spots occurring in later stages of infection; *C*, leaflet showing spotting on the lower surface.

are numerous on the foliage of plants in the field, the leaves become yellow and eventually wither and drop. This yellowing is less noticeable, however, on seedling plants. When conditions are especially favorable for stemphylium leaf spot, all the leaves may be killed except those near the tips and few fruits are produced. Spots also are sometimes formed on the stem, but this injury is not particularly severe.

The fungus is able to live for some time on the remains of plants in the soil, and much of the primary infection can be traced to this source. Seedlings often are infected as soon as they emerge and seedbeds are sometimes destroyed by the disease. Occasional infected plants can be found in abandoned fields and gardens during most of the year in Florida; the fungus spreads from such plants to later plantings.

Recommendations for Control

The control measures for stemphylium leaf spot are much like those for early blight (p. 20). Care should be taken to use clean seedbed soil, and the seed should be treated with bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67). In regions where the disease commonly occurs, the seedlings should be sprayed at weekly intervals

with one of the fixed copper compounds (p. 76) used at the same strength recommended for plants in the field. After the plants are well established in the field, spraying or dusting should continue at 7- to 10-day intervals if weather conditions favor the development of the disease. In the field any of the copper fungicides (pp. 76 and 77) may be used, but the fixed copper compounds are preferred.

None of the commercial varieties now in common use have shown any marked resistance to stemphylium leaf spot, but resistance has been reported in the Australian variety Targinnie Red and in the small-fruited currant tomato (*Lycopersicon pimpinellifolium* Mill.). Hybrids of this latter species with commercial varieties of tomato have given promise of definite resistance.

ANTHRACNOSE

Anthracnose, caused by *Colletotrichum phomoides* (Sacc.) Chester, is a common and widely distributed rot of ripe tomatoes. It often causes serious losses to canning crops in the Atlantic and Central States, but in regions where the fruit is harvested green for shipment to distant markets it is not of great importance. At first, infected fruits show small, slightly sunken, water-soaked, circular spots. These spots soon become darker and more depressed and have concentric-ring markings. The centers sometimes become tan and show numbers of dark specks, which are bodies in which spores of the fungus are produced (fig. 18). In moist weather these bodies often produce masses of salmon-colored spores, which give the centers of the spots a characteristic pink color. In warm weather the rot soon penetrates into the fruit and renders it worthless.

The fungus causing anthracnose occurs rather commonly in the soil, and the first infection appears to come from this source. The fungus penetrates apparently uninjured fruits and develops most rapidly in warm, damp weather. The spores are exuded in pinkish filaments on the surface of the spots and are splashed by rain to other fruits, on which they cause new infection. When conditions favor the spread of the fungus, many fruits are damaged in a short time.

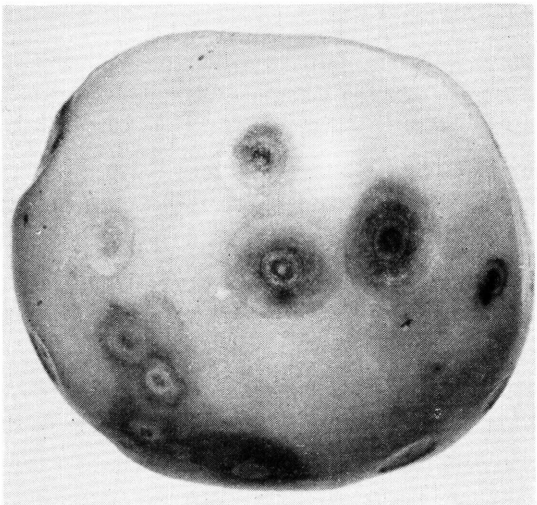

FIGURE 18.—Tomato showing the circular, sunken spots characteristic of anthracnose. Note the concentric markings in the centers of the spots. In wet weather the spots become covered with pinkish masses of the fungus spores, which are splashed by rain to other fruits.

Recommendations for Control

Anthracnose is likely to occur on poorly drained soils; such soils should be avoided. Since the fungus lives in the soil, a 4-year rotation is advisable. The organic fungicide zinc dimethyl dithiocarbamate (p. 77) seems to give better control of anthracnose than do the copper fungicides. Since this material also is very effective against early blight, the schedule of applications recommended for that disease (p. 20) will also care for anthracnose. If picking continues until late in the season, however, an additional application may be needed to protect late fruit. Another organic compound, ferric dimethyl dithiocarbamate (p. 78), also is effective against anthracnose but has not proved very effective against early blight. If it is used, it is best to make alternate applications of a copper fungicide, beginning and ending the series with the organic compound.

BACTERIAL SPOT

Bacterial spot, caused by *Xanthomonas vesicatoria* (Doidge) Dowson, is most noticeable in its effect on the fruit, but may also cause considerable injury to the foliage of seedlings and plants in the field. The disease has been reported from most tomato-producing regions and frequently causes considerable loss in the Middle and South Atlantic and Central States. It is most common in seasons with frequent rainy periods. Peppers also are subject to the disease and often are seriously damaged.

On the leaves the first symptoms are irregular, small, dark spots of a greasy appearance, the centers of which dry out and frequently tear. These spots are about one-eighth inch in diameter. Seedlings at times are badly damaged by this leaf infection, and the organism frequently causes some defoliation in older plants. There is also some spotting of the stems, particularly of seedling plants. At times infection of the flower parts causes a considerable amount of blossom drop. However, the disease is most noticeable on the green fruits, where the symptoms are small, water-soaked spots that become slightly raised and enlarged until they are one-eighth to one-fourth inch in diameter. Later the centers of these spots become irregular, light brown, and slightly sunken, with a rough, scabby surface (fig. 19). The spots do not extend very deep into the tissues. They can be distinguished from those of bacterial canker by the absence of the white border which surrounds the spots caused by the bacterial canker organism. Infection does not take place on ripe fruits.

The bacteria occur in great numbers in the spots on the leaves and fruits. The most general and severe infections occur during beating rains that splash the organism from plant to plant. Seed often becomes contaminated with the bacteria during extraction, and the organism can survive for some time on the surface. Much of the primary infection can be traced to this source, although under some conditions the bacteria may possibly overwinter in the soil.

Recommendations for Control

Seed disinfection with bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67) will free the seed from the bacterial spot organism. This is an effective means of control. After treatment, care should be taken that the seed is planted in soil that has not previously grown diseased plants or that has been disinfected before

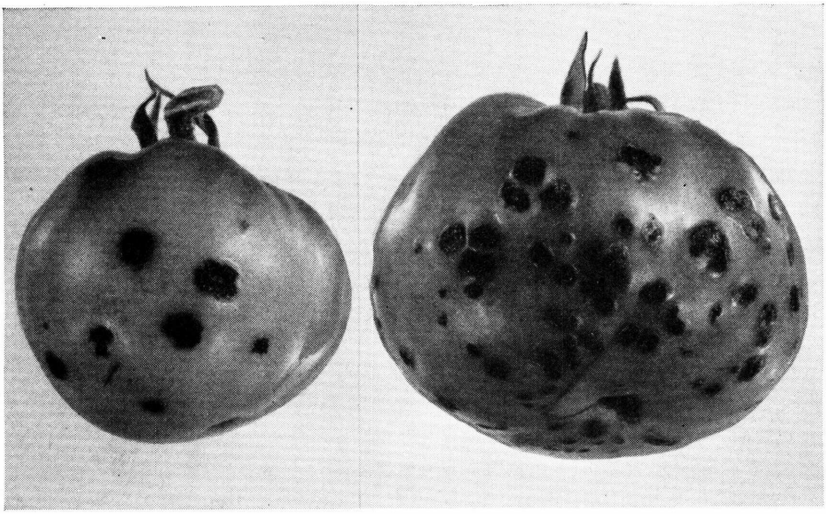

FIGURE 19.—Tomatoes affected with bacterial spot. The spots are raised at first but later are slightly sunken and have a scabby appearance. There is no light-colored margin as in the spots caused by the bacterial canker organism.

being planted. Spraying or dusting with copper fungicides (pp. 76 and 77) probably reduces leaf infection to some degree.

BACTERIAL SPECK

Bacterial speck, caused by *Pseudomonas punctulans* (M. K. Bryan) Dowson,[6] is occasionally found in the Atlantic and Central States, but it causes little serious loss. It is most noticeable on the fruit, where it causes numerous small, dark-brown, slightly raised spots that are less than one-sixteenth inch in diameter. The spots have definite margins and, like those of bacterial spot and bacterial canker, do not extend deep into the fruit (fig. 20). As both bacterial speck and bacterial spot may occur on the same fruit, the speck injury is frequently mistaken for small lesions of bacterial spot. Diseased leaves develop tiny dark spots about the size of those on the fruit. They extend through the leaf and, if numerous, cause yellowing of the surrounding tissue.

The disease is caused by a bacterium which, as far as known, affects only the tomato. Only young fruits are susceptible, and wounds are not necessary to infection. Infection occurs most abundantly after beating rains that splash the bacteria to all parts of the plant. It is probable that the organism is carried on the surface of the seed.

Recommendations for Control

Seed disinfection by bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67), as recommended for the control of bacterial spot, and the use of clean seedbed soil should also control bacterial speck.

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[6] Probably not *Bacterium tomato* (Okabe) Magrou, which does not produce symptoms on the fruit.

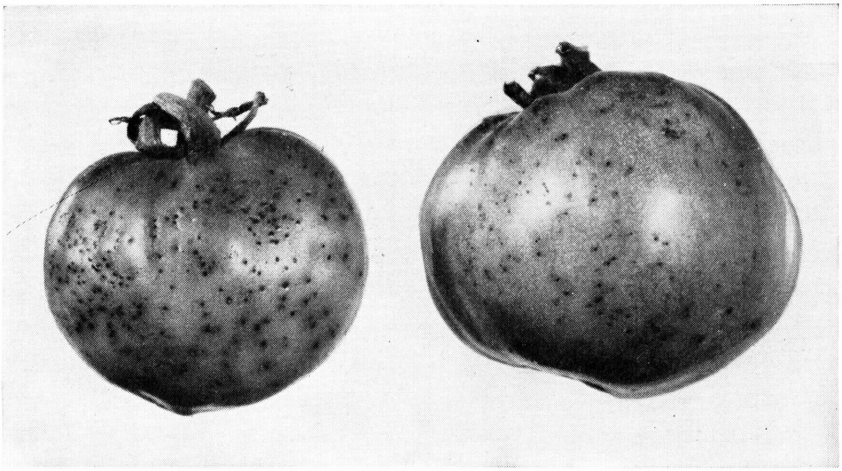

FIGURE 20.—Tomatoes showing bacterial speck. The spots are numerous and much smaller than those of bacterial spot.

BUCKEYE ROT

Buckeye rot is a fungus disease of tomato fruits that is most prevalent in regions subject to prolonged periods of warm, wet weather. In the field the rot is largely confined to fruits in contact with the soil; either green or ripe fruits may be infected. This rot occurs rather commonly in the South Atlantic and South Central States, where tomatoes are grown for shipment to northern markets, and causes loss on fruits in transit as well as in the field. The disease also is found in other tomato-producing regions, but ordinarily it is of only local importance there. In the Southeastern States the disease is commonly caused by *Phytophthora parasitica* Dast.,[7] but in California *P. capsici* Leonian and *P. drechsleri* Tucker appear to be responsible for most of the damage.

The first symptom is a grayish-green or brown, water-soaked spot that usually occurs where the fruit touches the soil. In warm weather the spots enlarge rapidly and may cover half or more of the fruit. They may have no definite markings but usually show darker zonate bands that give the disease its name "buckeye rot" (fig. 21). These markings are a distinguishing characteristic, but fruits affected with late blight rot occasionally show somewhat similar markings. Green fruits do not become soft for some time after infection. The surface of the spot is firm and has a smooth but not sharply defined margin. This distinguishes buckeye rot from late blight rot, whose spots have a roughened surface and are slightly sunken at the margins.

Buckeye rot is caused by a fungus that also affects the fruits of eggplants and peppers. The fungus lives in the soil and, since it requires abundant moisture for its development, is most common in poorly drained fields. It penetrates the uninjured surface of the fruit, and infection occurs either where the fruit touches the soil or where soil is splashed on the fruit surface by rain. When infected

[7] Synonym of *Phytophthora terrestris* Sherb.

just before harvest, fruits in green-wrap shipments often show no evidence of the disease when packed, but they develop the rot during transit and in the ripening rooms.

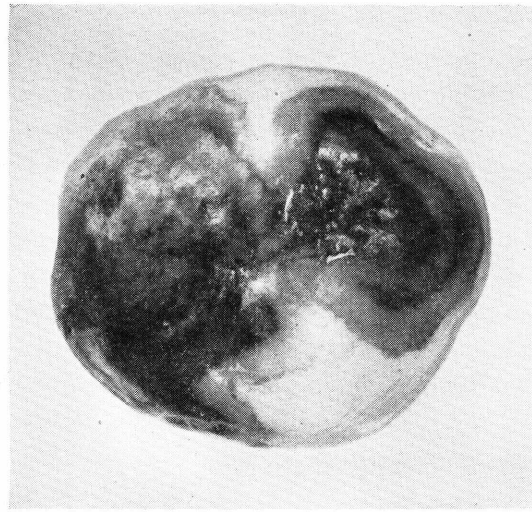

FIGURE 21.—Tomato showing the concentric markings and discoloration associated with buckeye rot. Fruits are infected by fungus spores from the soil.

Recommendations for Control

Since the fungus lives in the soil, tomatoes should not be planted for at least 3 years on land where the disease has occurred. Losses are most serious on poorly drained soils. When plants are staked to keep the fruit off the soil the losses are usually slight. A straw mulch that keeps the fruit off the soil and prevents splashing of soil onto the fruit by rain will help to prevent infection.

LATE BLIGHT

Late blight of tomatoes is caused by *Phytophthora infestans* (Mont.) DBy., a fungus which also causes late blight of potatoes. On the two hosts the leaf symptoms are similar. The late blight fungus causes severe defoliation of tomatoes and a destructive rot of the fruit. Late blight appears sporadically, and until 1945 losses were generally confined to the New England States and to certain sections of the Middle Atlantic, South Central, and South Atlantic States, with occasional damage in some sections on the Pacific coast. Until recent years this disease has rarely been of great importance in many of the canning-crop States east of the Mississippi; but of late there have been serious losses along the Atlantic coast and in some of the East North Central States. The disease is also sometimes damaging to greenhouse crops.

The first symptoms of the disease are irregular, greenish-black, water-soaked patches on the older leaves. These spots enlarge rapidly and in moist weather sometimes show a white, downy growth of the fungus on their lower surfaces. The stems also may show water-soaked, brown areas similar to those on the leaves. In moderately warm, wet weather the spread of infection is so rapid at times that almost all the foliage is affected and the plants look as though they had been damaged by frost.

Infection of fruit occurs at any stage of growth and is most common on the upper half but may occur elsewhere on the surface. The first symptoms are grayish-green, water-soaked spots that enlarge until they may cover half the surface. The spots become brown and have a firm, corrugated surface (fig. 22) that occasionally shows narrow,

zonate markings that may be confused with the broader markings of buckeye rot (p. 30). The margins of the spots may be somewhat indefinite but usually are slightly sunken where decayed and healthy tissues join. Under moist conditions a white, downy growth of the fungus appears on the fruit.

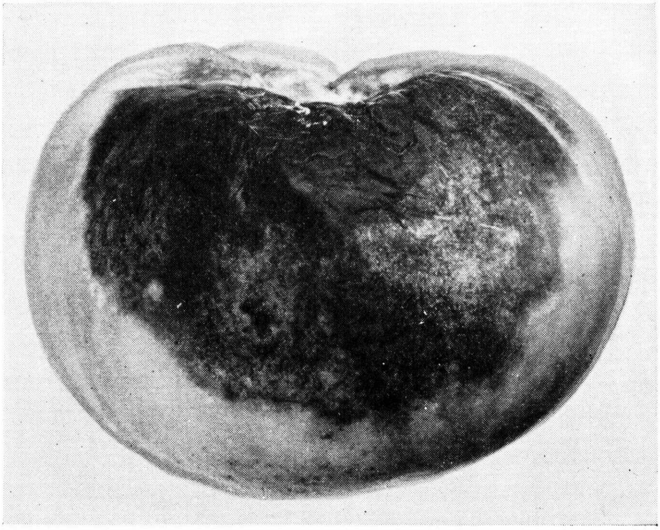

FIGURE 22.—Green tomato showing the discoloration and wrinkled appearance of the surface, resulting from infection by the fungus causing late blight.

In moist weather the fungus produces abundant spores on the undersurfaces of the leaves and occasionally on the fruit. These may be splashed to other plants by rain or carried some distance by the wind. Aerial spread of the spores may possibly be responsible for the gradual spread of the fungus over considerable areas. In the presence of moisture the spores germinate readily at temperatures of 40° to 70° F., but they are soon killed at 75° to 80° in dry weather. After infection occurs the fungus invades the plant rapidly at temperatures of 70° to 80°. Cool nights and only moderately warm days with abundant moisture favor development of late blight. Mean temperatures much above 70° are likely to check it, especially in dry weather. Fruits show decay within a week after infection, and many that seem sound when taken from fields where late blight occurs may decay by the time they reach market.

Phytophthora infestans does not seem to survive in dead plant tissue, but it does persist in infected potato tubers. It is probable that late blight of tomatoes is caused by a strain of the fungus somewhat different from that commonly found on potatoes. Apparently the tomato strain at times infects potato plants and can be recovered from their tubers as a typical tomato strain. Reports also indicate that what appears to be the usual potato strain will cause only mild symptoms when first transferred to tomatoes, but it can develop and retain the typical virulence of a tomato strain after passage through several tomato plants. Blighted potato plants, therefore, are potentially an important source of infection for tomatoes.

Recommendations for Control

Late blight can be successfully controlled by spraying with a fixed copper fungicide (p. 76) or with bordeaux mixture (p. 77). Good control has also been obtained by spraying with disodium ethylene bisdithiocarbamate (p. 78), used with zinc sulfate and lime, or with zinc ethylene bisdithiocarbamate (p. 78). Spraying is preferred to dusting, but fixed copper dusts can be effective if properly applied. When late blight threatens, spraying should begin at once and if necessary should continue well into harvest. Sprays should be applied at intervals of 5 to 10 days, depending on the weather. Not over 7 days should elapse between applications of dusts. It is better not to follow potatoes with tomatoes on the same field and to avoid planting these two crops in adjacent fields.

PHOMA ROT

Phoma rot of tomatoes, caused by *Phoma destructiva* Plowr., is responsible for losses of fruit shipped from the South Central and South Atlantic States during fall, winter, and early spring. Minor losses have been reported from the Middle Atlantic and North Central States.

On the leaves the first symptoms are small, irregular, dark spots that may occur in great numbers. These soon become one-fourth to one-half inch in size and show zonate markings (fig. 23) that may be mistaken for those caused by early blight or nailhead spot. Severely infected leaves turn yellow and wither. The stems show dark, elongated spots with faint, concentric markings. Seedling tomatoes may be severely injured by leaf and stem infections.

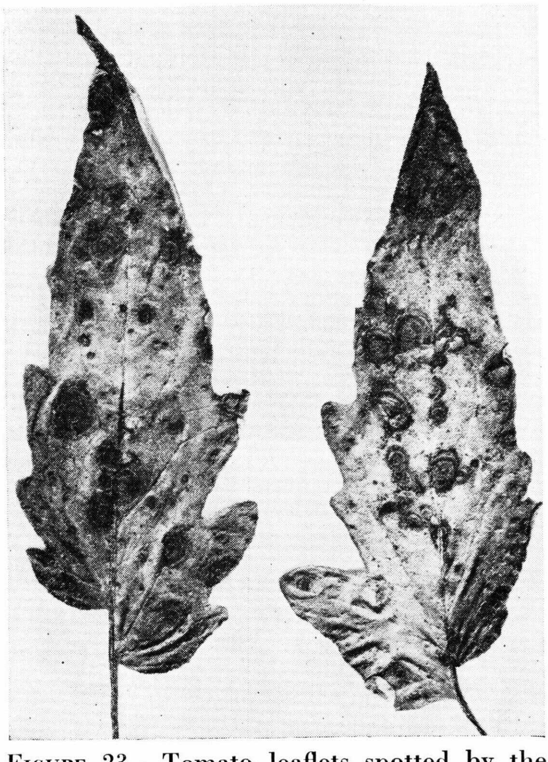

FIGURE 23.—Tomato leaflets spotted by the fungus causing phoma rot. Note the concentric markings, which resemble those of early blight.

The greatest losses from spotting of the fruit occur during transit and in ripening rooms, but fruits also are damaged in the field. The field symptoms commonly consist of small (1/8-inch), slightly depressed spots near the stem scar that become brown and develop tiny pustules (pycnidia) in which the fungus spores are produced. On green fruits

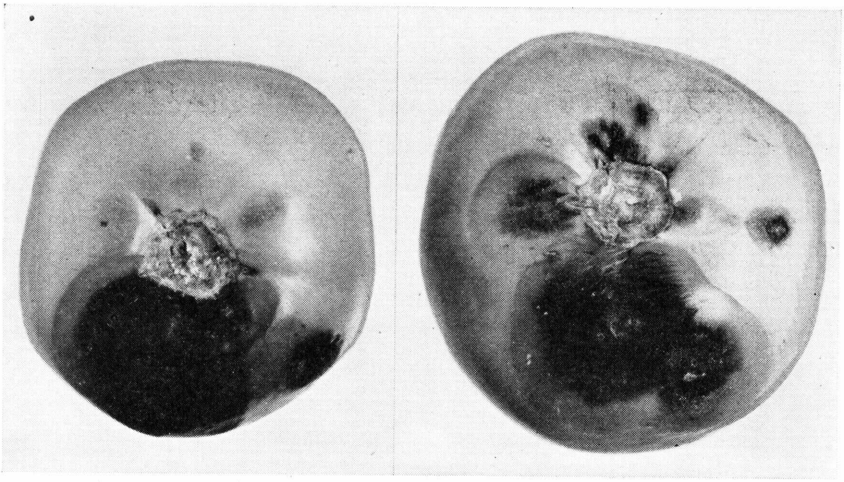

FIGURE 24.—Ripe tomatoes showing an advanced stage of phoma rot. The centers of the spots are dark and leathery with lighter margins.

ripening after shipment the spots develop more rapidly and appear first as circular, depressed, water-soaked areas that may become ½ to 1½ inches in diameter. These spots become black and leathery and are dotted with the minute pustules (fig. 24). Such spots are most common near the stem scar but may also develop at other points on the surface.

The fungus causing phoma rot can live for a time on decaying plant refuse in the soil, and much of the primary infection comes from this source. Seedling infection is common, and the disease is often carried to the field on infected plants. In the field, masses of spores are exuded from the pustules in the spots on the leaves during wet weather and are washed onto the surface of the fruit by rain or are spread by those working among the plants. Since fruits are infected only through breaks in the surface, infection is more common during shipment and ripening, because of slight injuries previously received in picking and packing. When the disease is prevalent in the field, the fungus spores are often widely distributed over the fruit during the washing and packing processes, and the high humidity that usually prevails during shipment and ripening favors infection. This infection occurs most frequently through stem scars, growth cracks, and other injuries about the stem end of the fruit, but spotting may occur at other points and frequently follows the injuries caused by nailhead spot.

Recommendations for Control

In sections where phoma rot occurs, great care should be taken to locate seedbeds on clean soil and at a distance from land that has grown tomatoes during the previous season. Seed should be disinfected with bichloride of mercury (p. 68) or ethyl mercury phosphate (p. 67), and the seedlings should be sprayed at weekly intervals with a fixed copper spray (p. 76) as soon as the true leaves appear. Plants in the field should be sprayed with a fixed copper compound or bordeaux mixture (p. 77) at intervals of 10 days, beginning soon after the plants are set, unless the weather remains warm and dry for some time after transplanting.

Fruits should be handled carefully in picking and should not be picked when the plants are wet, in order to avoid spreading the spores to foliage and fruits. The Florida Agricultural Experiment Station has reported that washing the fruit immediately after picking with a 5-percent borax solution, containing one-half of 1 percent of liquid tar soap as a wetting agent, is likely to reduce the amount of infection occurring on fruit in transit and storage.

SOIL ROT

Soil rot of tomato fruits is caused by the fungus *Rhizoctonia solani*, which is likely to be present in the soil wherever tomatoes are grown in the field and which also may cause damping-off (p. 16) and girdling of seedling plants. The rot occurs most commonly on fruits whose surfaces have been in contact with the soil; it is found on fruits both in the field and in transit. The first symptoms appear as brown, slightly sunken spots about three-fourths inch in diameter (fig. 25); the spots have sharply outlined, concentric zonate markings that are narrower and closer together than those of buckeye rot (fig. 21). These spots gradually enlarge until they may be more than an inch in diameter, and the markings tend to become less evident. As they enlarge, the spots become dark brown, and the centers frequently break open. This rupturing of the surface of the spots, as well as the narrowness of their concentric markings, distinguishes the disease from buckeye rot.

The fungus causing soil rot penetrates the fruit through wounds or the unbroken epidermis. Infection is most common during periods of wet weather on moist soils where the vines cover the ground. Moderate temperatures also favor the development of the disease. Infection is not likely to occur except where fruits are in contact with the soil or where soil has been splashed on them by rain.

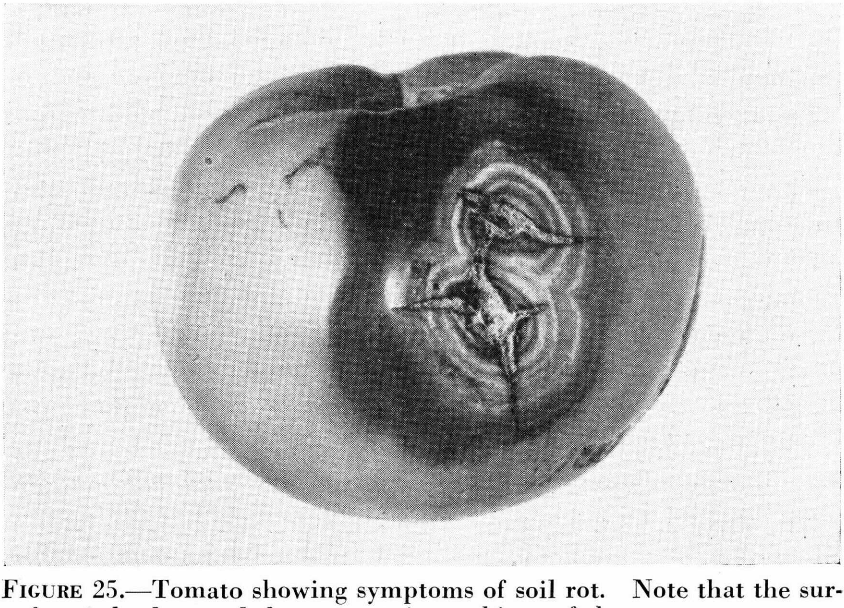

FIGURE 25.—Tomato showing symptoms of soil rot. Note that the surface is broken and the concentric markings of the spot are narrower and more sharply outlined than those of buckeye rot.

Recommendations for Control

Since soil rot is most common on wet soils, its occurrence can often be prevented to a considerable extent by avoiding the planting of tomatoes on low, poorly drained land. In small plantings the staking of the plants will almost eliminate the disease. Spraying is of little value as a means of control.

MINOR FRUIT ROTS

The tomato fruit is subject to a number of rots caused by species of *Fusarium*, *Oospora*, *Cladosporium*, *Pleospora*, *Rhizopus*, *Botrytis*, and other fungi and by various bacteria, particularly *Erwinia aroideae* (Townsend) Holland and *E. carotovora* (Jones) Holland. These rots are not of great economic importance since many of these organisms do not attack leaves or stems and in many instances infect the fruits only through growth cracks, insect punctures, mechanical injuries occurring in harvesting and packing or the lesions caused by the common fruit-spotting organisms. Fruits that show these rots in the field, however, are so severely damaged as to be worthless, as the progress of the invading organisms is commonly rapid and many of the rots are of a soft, watery type with an odor of fermentation. Green mold rot, caused by a species of *Cladosporium* other than that causing leaf mold, and pleospora rot, caused by *Pleospora lycopersici* E. and C. Marchal, are responsible for some losses on green-wrap fruits during transit and ripening, but these losses are usually of local importance only. With these last-mentioned diseases often there may be little evidence of disease in the field, but the fungi are present on the fruits and develop under the favorable conditions of humidity and temperature that occur during shipment and ripening. The bacterial rots are of a soft, watery type, and the fruits often resemble a bag filled with a liquid mass of decayed tissue. Bacterial rots occur as secondary infections of injured fruits.

Recommendations for Control

Losses in transit can be reduced to some extent by taking care to avoid mechanical injuries in harvesting and packing the friuts. Also plants grown on well-drained soil are less likely to suffer from these fruit rots than those grown where drainage is poor. Generally there is little field injury except when rainfall is unusually abundant, and even then the damage is usually of only local importance.

VIRUS DISEASES

Most of the virus diseases of tomatoes are more or less prevalent wherever this crop is grown and occur both in the field and the greenhouse. Two diseases, curly top and spotted wilt, however, are found only where certain specific insect carriers are abundant.

In general, the symptoms of virus infection on the leaves consist of various types of mottling, curling, or distortion and, in some diseases, of spotting or withering of the leaflets. Certain viruses also cause a streaking of the stem that may kill the growing tips; with these the fruits at times are mottled, spotted, and misshapen. Some of these diseases may not always seriously reduce the amount and quality of the fruits, but others stunt and damage the plant so severely that few, if any, marketable fruits are produced.

Tomato mosaic, as the name is ordinarily used, refers to a virus disease found in fields and greenhouses throughout the United States. The virus causing this disease is the same as that causing the common mosaic of tobacco. It also affects peppers, eggplants, petunia, and a large number of other solanaceous plants and some plants of other families. The ordinary green form of mosaic causes a light- and dark-green mottling of the tomato foliage, accompanied by some curling and malformation of the leaflets (fig. 26, *A*). Plants may be somewhat

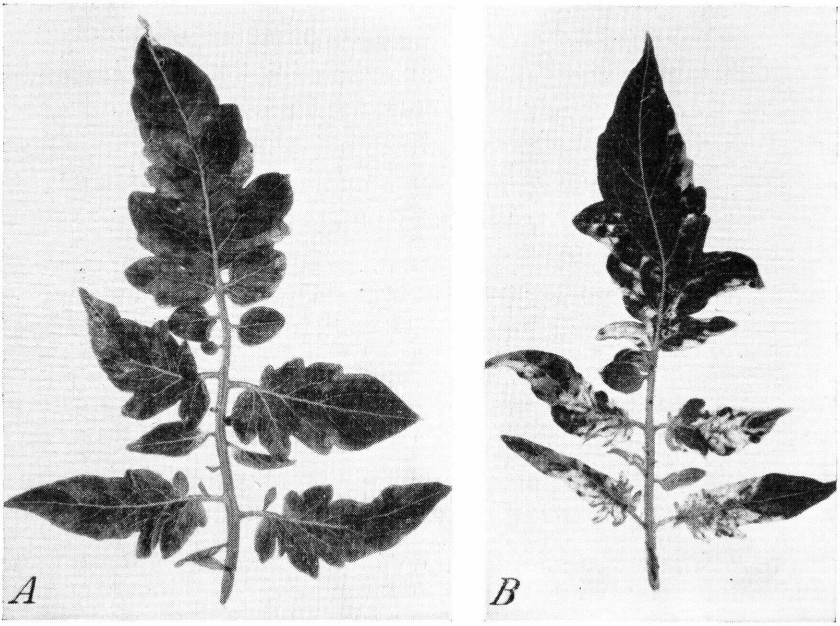

FIGURE 26.—Tomato leaves showing symptoms of green (*A*) and yellow (*B*) strains of ordinary tomato (tobacco) mosaic. The green mottling is much less marked than the yellow form.

stunted if infected when small, but in those infected after they reach the fruiting stage there is no great reduction in the size or number of fruits.

Certain yellow strains of this virus, which cause a striking yellow mottling of leaves (fig. 26, *B*) and may also mottle the stems and fruits (fig. 27), are often found. This yellow mosaic often causes distortion, curling, and dwarfing of the foliage, and may cause a serious reduction in yield.

Other strains of the tomato virus that may cause spotting of the leaflets and blemishes of the fruit are known to occur, but these have not been commonly found in the field and are of minor importance.

Although the common types of tomato mosaic may not always cause a marked reduction in the yield and quality of the fruits they do cause some lowering of vigor in the plant, and every effort should be made to prevent this virus infection. Prevention of infection is also important because plants infected with tomato mosaic may also become infected later with a potato virus. This combined infection causes

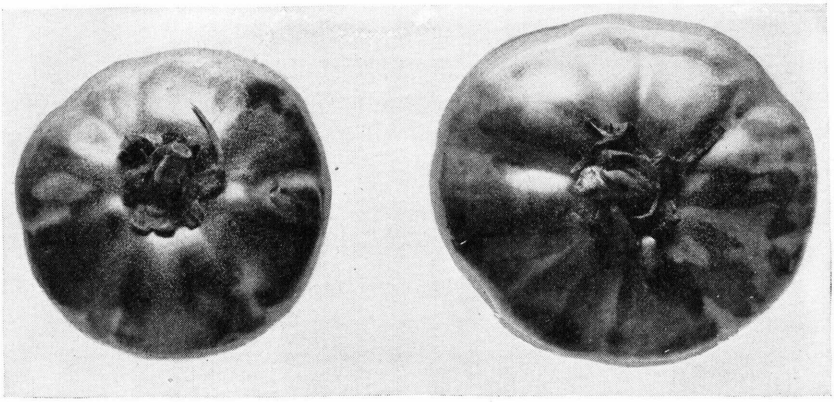

FIGURE 27.—Tomatoes affected with yellow mosaic. These markings usually occur on the shoulders of the fruits.

a disease (double-virus streak) so severe that the plants are almost worthless (p. 42).

The mosaic virus is spread by the handling of both mosaic and healthy plants in transplanting and by brushing against plants during hoeing and cultivating. In the greenhouse the virus is readily transmitted in tying and pruning the vines, and most greenhouse plants are usually infected before the end of the season. The disease also may be transmitted to tomatoes by certain species of aphids, but these insects are not so important as human beings in the general spread of the disease.

The virus of tomato mosaic will live for several years in dried leaves and stems, and in greenhouses infection at times occurs from the remains of a previous crop of mosaic plants in the soil. This type of infection is, however, most common where one crop of tomatoes is immediately followed by another. In the field the soil does not seem to be the source of much infection. The virus is also found on the surface of seed taken from mosaic fruits; if such seeds are planted almost at once after extraction, an occasional case of seed transmission has been known to occur. In commercial practice, however, where the seed has been dried for some time before planting, there is little if any seed transmission of the virus.

The virus of tomato mosaic also infects certain perennial solanaceous weeds, particularly groundcherry and horsenettle. These plants may serve as sources of infection through the agency of aphids, which in feeding transmit the virus from the wild to the cultivated host. Also seedlings intended for field planting are often infected when grown in or near a greenhouse where the disease is present on a crop of older plants. This infection usually results from workers' handling the seedlings after working with the older mosaic plants, but it may occur through transmission by aphids.

As already mentioned, the tomato mosaic virus is the same as that of ordinary tobacco mosaic. This virus remains active in dried tobacco leaves for a long time and is present to some extent in cigar, cigarette, and pipe tobaccos. Therefore smokers are likely to carry the virus on their hands; it is probable that the greatest portion of the initial mosaic infection on tomato seedlings can be traced to this source. Tobacco manufactured for chewing contains comparatively little of

the virus, but the socalled natural leaf is likely to have a high virus content.

Recommendations for Control

The control of tomato mosaic must be based on the protection of the seedlings from infection, since, after the disease is once established in the field or greenhouse, there is little that can be done to prevent its spread during the handling and pruning necessary to the production of the crop. Certain practices, if carefully followed, will reduce or eliminate the sources of infection of seedling plants and thus aid in preventing infection during the early part of the season when the plants are most likely to be seriously injured.

Care should be taken to avoid unnecessary handling of the seedlings, and the hands should be washed with soap and water before seedlings are handled, since it has been found that such washing will free the hands of the mosaic virus. Workers should not smoke or chew tobacco while handling seedlings, but they may be allowed to smoke at stated intervals if their hands are washed before they touch the plants again. If seedlings are grown where there is also a bearing crop of greenhouse plants infected with mosaic, it is best to do all the handling of the seedlings before starting work with the older vines. If this is not done, the hands should be washed before work on the young plants is started. The importance of handling as a means of infection is indicated by the fact that plants grown directly from seed in the field show almost no mosaic until they reach a considerable size.

Weeds should be kept down in the vicinity of seedbeds and fields in order to prevent infection from weed hosts. Field plantings of tomatoes should not be made near greenhouses where a fall crop is to be grown, since the virus may be carried from the field to the greenhouse by insects or human beings.

Mosaic seedlings found in seedbeds or coldframes should be removed at once without being brushed against the healthy plants, and then the hands should be washed before touching healthy seedlings. However, the removal of older mosaic plants from the field is rarely of much value in stopping the spread of mosaic, and this practice is not recommended. Although the same is true of greenhouse plants after they become large enough to require tying and pruning, the removal of small plants showing mosaic is advisable. When such plants are removed, however, they should not be replaced by healthy plants, since infection is almost certain to occur from the remains of mosaic roots in the soil. Spraying and dusting are of no value in the control of mosaic, except as they are used for the control of aphids.

CUCUMBER MOSAIC

Wherever tomatoes are grown they may at times be infected with the virus causing mosaic of cucumbers and melons, but such infection is comparatively rare, partly because the cucumber virus, unlike that of ordinary tomato mosaic, is not easily transmitted to tomatoes by brushing against or handling the plants. As this virus does not withstand drying, it will not persist in the soil and does not remain active for any length of time on the hands or clothing. Therefore the greater part of the infection on tomatoes occurs through the agency of aphids, but as the tomato is not a preferred host of the aphid that commonly feeds on cucumbers and melons, such infection is not particularly common.

Tomato plants affected with cucumber mosaic are usually considerably stunted. The leaves, although showing a milder green mottling than those affected with the ordinary tomato mosaic virus, are extremely distorted and malformed. Frequently the leaflets consist of little but a central rib and have a "shoestring" appearance that is typical of this disease (figs. 28 and 29, *A*). This "shoestring" symptom is characteristic of cucumber mosaic and does not occur in plants affected with ordinary tomato mosaic. It is often confused, however, with a symptom of tomato mosaic known as "fern leaf" (fig. 29, *B*), which is sometimes found on plants grown under glass during the short days of fall and winter. In "fern leaf" the blade of the leaflet is not so completely suppressed as in a "shoestring" leaflet but is abnormally long and narrow.

In the field the cucumber virus causes a pronounced dwarfing of the plant and the internodes of the stem are so shortened as to give the plant an abnormally compact and bushy appearance when compared

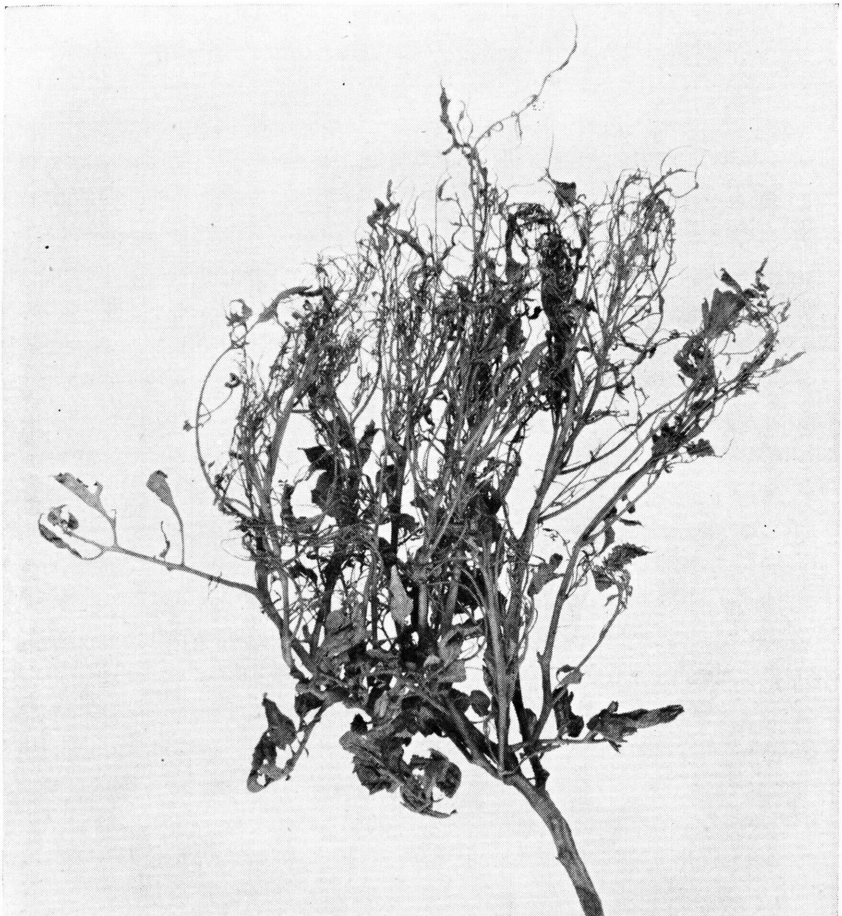

FIGURE 28.—Tomato plant infected by the cucumber mosaic virus, showing extremely filiform ("shoestring") foliage.

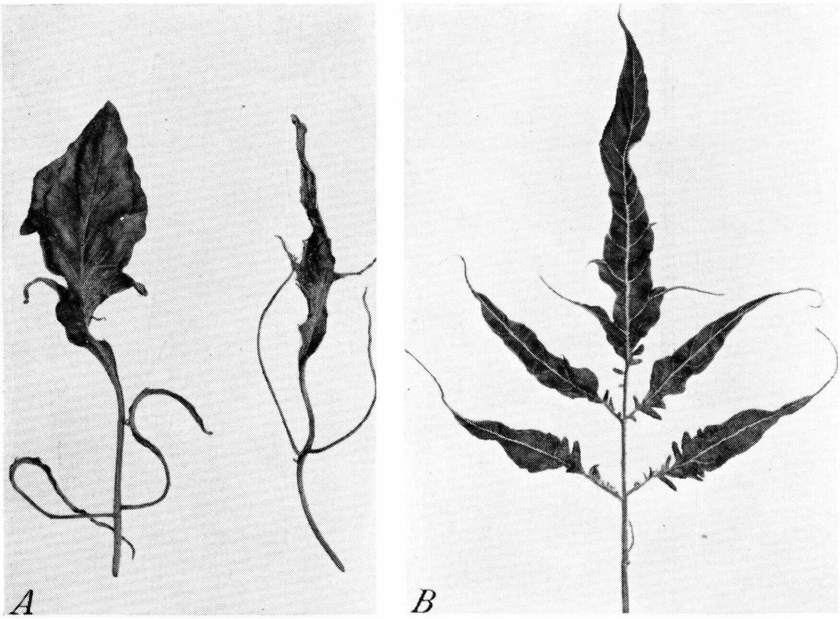

FIGURE 29.—Tomato leaflets showing (*A*) the "shoestring" symptom caused by the cucumber mosaic virus and (*B*) the "fern-leaf" symptom sometimes found during the winter months on plants infected by ordinary tomato mosaic. The "fern-leaf" symptom is not typical of cucumber mosaic.

with those infected with the ordinary tomato mosaic. These stunted plants set only a few fruits, which are usually small.

Occasionally greenhouse plants infected with ordinary tomato mosaic may later be further infected with the cucumber mosaic virus. Such plants remain short, and the leaves near the growing point show a peculiar bushy and upright habit of growth. The young leaflets are curled and distorted, and a few may show the "shoestring" malformations typical of cucumber mosaic. The older leaves show a mild mottle accompanied by a purpling of the veins and are rolled upward at the margins. Many of the blossoms are malformed and abortive, and the fruits produced are likely to be deeply ridged and show protuberances at the blossom ends. This double infection occasionally causes serious losses on greenhouse tomatoes.

Recommendations for Control

There are a number of perennial weed hosts of the cucumber mosaic virus, particularly catnip, milkweed, pokeweed, and groundcherry. These weeds serve as a source of virus infection through the agency of aphids, which feed on both wild and cultivated hosts. Care should be taken to keep down all perennial weeds about the greenhouse, seedbeds, and fields since this will aid in preventing infection, not only of tomatoes but also of cucumbers, muskmelons, celery, and peppers, all of which are susceptible to cucumber mosaic.

Cucumbers and melons should not be planted close to greenhouses in which a fall crop of tomatoes is grown. If this is done, some of the

aphids present on the vine crops when they mature in the fall are likely to enter the greenhouses. If mosaic has occurred on the cucumbers or melons, as is usually the case, these aphids may carry the virus to the tomatoes. The same precaution applies to celery and peppers because these crops also are commonly affected by cucumber mosaic.

Since there is always likely to be some movement of aphids in the fall, it is advisable to fumigate the greenhouses regularly until several periods of freezing weather have occurred. If this is done, it is ordinarily possible to prevent any general infection with cucumber mosaic.

DOUBLE-VIRUS STREAK

The most common and damaging form of streak is that caused by a combined infection with the ordinary tomato mosaic virus and the so-called latent virus that is found in nearly all, if not all, plants of the older standard varieties of potatoes grown in this country. This potato virus causes few or no visible evidences of disease in potatoes; and, when healthy tomato plants are inoculated with the juices from the tops or tubers of potatoes that carry it, only a very mild mottling appears on the foliage and no symptoms occur on the stems or fruits. However, if plants already infected with the tomato mosaic virus are

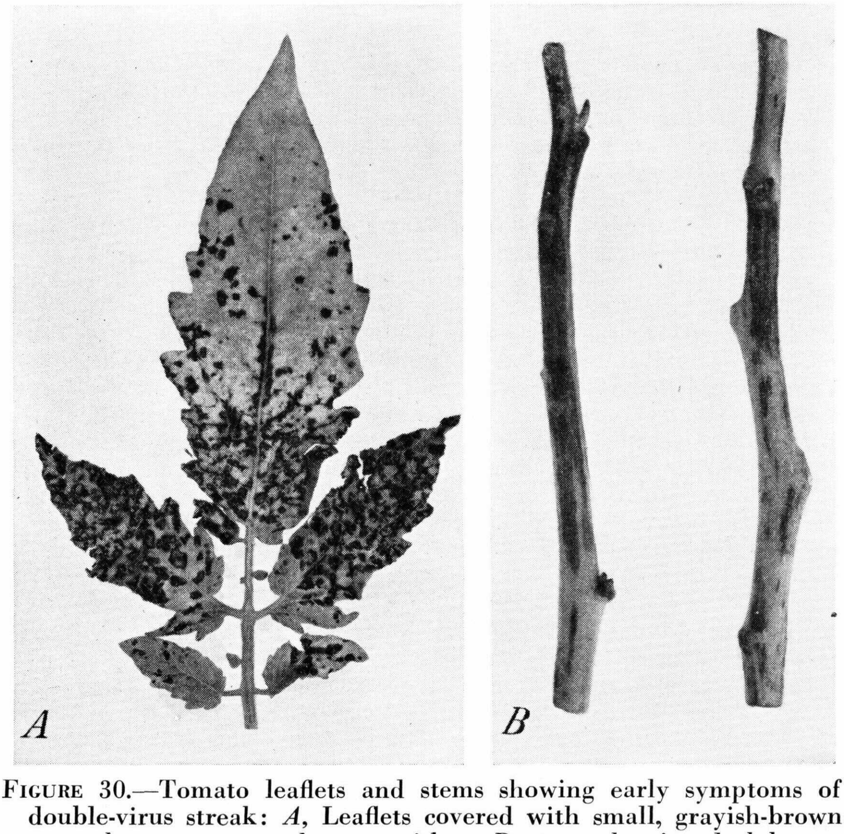

FIGURE 30.—Tomato leaflets and stems showing early symptoms of double-virus streak: *A*, Leaflets covered with small, grayish-brown spots that soon cause them to wither; *B*, stems showing dark-brown streaks of different widths and lengths.

later infected with this potato virus, a very serious disease known as double-virus streak is the result. This disease often causes serious losses to greenhouse crops and is occasionally found in the field wherever tomatoes are grown.

The first symptom is a light-green mottling of the leaves, accompanied by the development of numbers of small, grayish-brown, dead spots, which have a thin, papery appearance (fig. 30, *A*).

Many of these leaves may wither and die in the early stages of the disease. The later growth is mottled green and yellow, dwarfed, and much curled, with small, irregular, chocolate-brown spots scattered over the leaflets. On the stems and leaf petioles there are numerous narrow, dark-brown streaks that give the disease its name (fig. 30, *B*). This streaking varies in severity. When plants are infected while small the tips occasionally die.

Infected plants are stunted, and the later growth of foliage may be a somewhat more yellow green than that of healthy plants. The streaked plants set comparatively few fruits. These fruits are often rough and misshapen, and on the surface they have small, irregular, greasy, brown patches, one-eighth to three-eighths inch in diameter, which render them unfit for market (fig. 31).

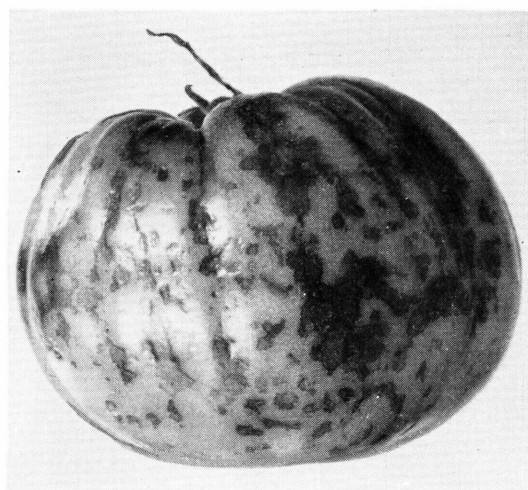

FIGURE 31.—Tomato affected with double-virus streak. The spots are light brown and do not extend deep into the fruit.

There are a number of strains of the latent potato mosaic virus, which vary in the intensity of the symptoms they produce on certain hosts. The severity of the double-virus streak symptoms on tomatoes varies with the virulence of the strain of the latent virus with which they are infected, but some spotting of the leaves and streaking of the stem occur with all strains.

The potato virus is present in the tubers, and some of the initial infection in the greenhouse probably results from the virus being carried on the hands of the workers who cut or peel potatoes shortly before they tie or prune the tomatoes. In the field the potato virus may be transmitted to tomatoes by the hands, clothing, or tools of those who previously have worked in adjacent potato fields. When young plants are grown in the greenhouse for transplanting in the field, they may become infected from older plants in adjacent houses. The potato virus apparently is not spread by aphids, and these insects, therefore, are not a factor in transmitting streak. When once introduced into the greenhouse, the combined viruses are rapidly spread by those working with the plants, and serious losses usually result if streak appears early in the season.

Recommendations for Control

The recommendations already given for the prevention of infection by the tomato mosaic virus (p. 39) also apply to double-virus streak, since the tomato mosaic virus is always present in streaked plants. If those recommendations are followed, the likelihood of losses from streak will be reduced; but, to avoid the occurrence of the double-virus streak, it is also necessary to guard against infection of the plants with the latent potato mosaic virus.

To avoid such infection, all workers should be required to wash their hands when reporting for work each day, since, if they have previously cut, peeled, or handled potatoes, their hands may carry the virus. Those who have worked among potato plants in home gardens also may carry the virus as a result of handling the plants. Potatoes should not be grown near the greenhouse because of the danger of such infection, and it is best not to plant tomatoes next to potatoes in the field. In regions where the winters are not severe, volunteer potato plants often appear in fields where potatoes were grown during the preceding year. These serve as sources of infection for tomatoes; it is best to let at least 2 years intervene between crops of potatoes and tomatoes in the same field.

If the young plants in the greenhouses show symptoms of streak, they should be removed. In doing this, care should be taken not to brush the vines against healthy plants, and the hands should be washed before again touching healthy plants. If the plants are carefully watched while small and if the first infection occurs on only a few plants, an outbreak of streak can sometimes thus be prevented. After the disease is well distributed throughout the greenhouses, however, such measures are of little value because plants recently infected carry the virus before showing any pronounced symptoms. Such plants often serve as sources of infection before the disease can be detected. Under these circumstances the new infections occur so rapidly that the removal of the diseased plants does not check the spread of the disease.

SINGLE-VIRUS STREAK

Another form of streak is occasionally serious in the greenhouse but is rather rare in the field. This disease is caused by a single virus much like that of tomato mosaic; one of the symptoms is a green mottling of the leaves that is indistinguishable from that of tomato mosaic. The infected plants may show no symptoms other than this mottling. But under some conditions that are not entirely understood the stems develop broad brown streaks; in such stems the pith shows brown shriveled areas which are not found in plants affected with double-virus streak. The leaves of plants with stem streaks show small, irregular, dark-brown lesions or at times linear "oak leaf" markings; the later growth shows only a green mottling. The fruits of the streaked plants may not be affected, but they often are marked with rather broad, depressed brown rings about one-half inch in diameter (fig. 32). This discoloration first appears as a slightly depressed, narrow ring on the surface of the green fruit and later changes to a broader brown marking. In ripe fruits there is no yellowing of the surface about these ring markings. Single-virus streak is much less common than the double-virus type, and, when it occurs, the losses usually are less severe.

The virus, like that of a tomato mosaic, is spread by pruning or handling the plants. It does not appear to be commonly transmitted through the seed but may live for a few months in greenhouse soil.

Recommendations for Control

The recommendations given for preventing infection by the tomato mosaic virus (p. 39) will also aid in keeping plants free from single-virus streak. However, it is not known that this latter virus occurs in manufactured tobacco. The recommendations regarding the removal of diseased plants are the same as those for double-virus streak (p. 44).

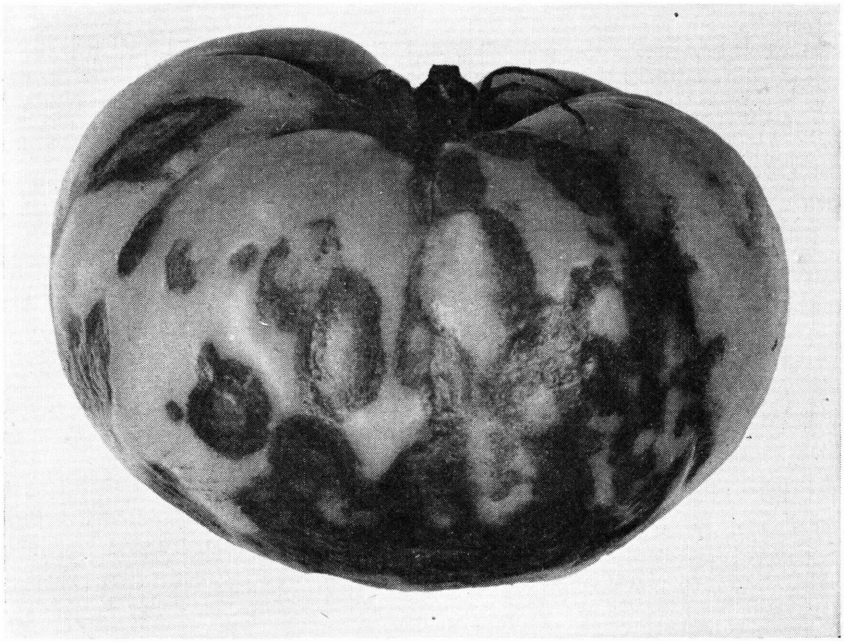

FIGURE 32.—Tomato showing the circular markings caused by single-virus streak.

SPOTTED WILT

The disease known as spotted wilt is similar to the streak diseases just described in that it causes streaking or spotting of the leaves, stems, and fruits. However, it is more severe in its effect and, unlike the streak diseases, attacks a great number of ornamental plants, weeds, and vegetable crops. The spotted wilt virus is transmitted by flower and onion thrips; although also transmissible by mechanical means, it apparently does not occur to any extent unless the insect carriers are present in considerable numbers. The disease has caused serious losses in some sections of California and in Oregon, where a very damaging strain of the virus causes what is known as tip blight. The disease occasionally occurs in the field in some of the East North Central and Atlantic States and at times has caused serious losses on greenhouse crops.

In young, rapidly growing tomato plants, the first symptoms are numerous small, dark, circular, dead spots on the younger leaves. These leaves may have a peculiar bronzed appearance, and the badly spotted leaves may soon turn dark and wither (fig. 33).

The tips of the stems of such plants commonly show dark streaks, and the growing points frequently wither. Young plants may be killed; if they survive, the new growth is much dwarfed and the leaflets show a distortion similar to that caused by mosaic.

On older plants there is also more or less damage to the growing tips, and the foliage may be somewhat yellowed. The fruits of these plants show numerous spots about one-half inch in diameter, with circular markings which show as concentric bands of red and yellow on ripe fruits (fig. 34). The centers of these spots often may be so raised as to give the fruit a rough appearance. The fruit symptoms are one of the most characteristic features of the disease.

The spotted wilt virus also affects lettuce, celery, spinach, potatoes, and peppers and is found on weeds such as mallow, jimsonweed, and wild lettuce. It also affects a great number of ornamental plants, par-

FIGURE 33.—Leaf of tomato plant infected by the spotted wilt virus. Note that the leaflets are covered with small dark spots and that some have been killed. Such leaves often have a bronze color.

ticularly dahlias, calla lilies, nasturtiums, petunias, and zinnias. When these plants are infected with the virus they may serve as sources of infection for tomatoes if thrips are present. Dahlias frequently seem to be such a source of infection, especially when they are propagated in or near greenhouses where tomatoes are being grown.

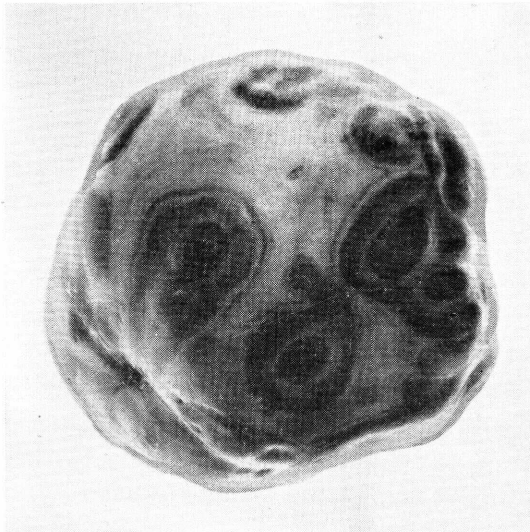

FIGURE 34.—Tomato showing the concentric markings caused by the spotted wilt virus. On ripe fruit these consist of alternate zones of red and yellow. The spots give the fruit a rough appearance.

Recommendations for Control

Where spotted wilt is prevalent, it occurs on so many plant species that sources of infection are abundant. Some protection can be obtained, however, if tomato fields are kept isolated from home gardens and commercial plantings of ornamentals. Weeds should be kept down in the plant beds and fields. Tomato plants that show the disease when small should be removed, since, unlike those affected with tobacco mosaic, they can be replaced with healthy plants without the likelihood that these will also be infected. The control of thrips by insecticides has not been sufficiently effective until recently to check the spread of spotted wilt, but it is possible that considerably better results may be obtained with some of the materials that have recently come into use.

Ornamentals should not be grown in or near greenhouses used for tomatoes. If diseased plants are found, they should be removed and insecticides should be used regularly each week for the control of thrips.

The Hawaii Agricultural Experiment Station has introduced Pearl Harbor, a variety that is resistant to the strain of spotted wilt virus found in Hawaii. This tomato is a rather early, red variety of determinate growth.

CURLY TOP

Curly top, or western yellow blight, of tomatoes is caused by the virus that causes curly top of sugar beets. It is a destructive disease of tomatoes and often causes serious losses to other vegetable crops, particularly beans, table beets, spinach, squashes, and peppers. The disease is especially important on tomatoes and other vegetables in irrigated and dry-farming sections of Utah, California, southern Idaho, and the eastern parts of Oregon and Washington. Some losses also occur in certain sections of western Colorado and Texas, and the disease has been reported in Arizona, Nevada, New Mexico, Montana, and western Nebraska.

The virus of curly top is not transmitted through the seed or soil, nor is it spread by contact of diseased and healthy plants or by the handling of plants by the grower. It appears to be disseminated only by a single insect species, the beet leafhopper (*Eutettix tenellus* (Bak.)). This is a migratory insect that has its breeding grounds in weedy, abandoned lands and sagebrush areas of the semiarid areas west of the Rocky Mountains. Therefore, the geographical distribution of the disease is limited to the range of the leafhopper. At times the disease assumes epidemic form in some sections of the mountain and Pacific coast regions, and losses often are severe. In those sections where great numbers of the leafhoppers appear each year, it is almost impossible to grow profitable crops of tomatoes, beans, spinach, and other curly-top-susceptible plants.

The tomato is susceptible to infection by the curly top virus at any stage of growth, but this susceptibility decreases markedly with increasing age of the plant. Infected seedlings soon show a yellowing of the foliage that may be accompanied by some curling and twisting of the leaves. Such plants ordinarily die within a short time.

On plants that are well established in the field the first symptoms consist of a pronounced upward rolling and twisting of the leaflets that exposes their undersurfaces, a stiff and leathery condition of the foliage, and a peculiar dull yellowing of the entire plant. The branches and stems become abnormally erect, and the petioles of the leaves curl downward. There often is some purpling of the veins of the leaflets, and the plant usually is much stunted (fig. 35). Many of the roots and rootlets are killed, and as a rule the plants gradually succumb. Very few, if any, fruits are produced after infection, and those which are already set turn red prematurely. All the standard cultivated varieties of tomatoes are severely injured by curly top. Early varieties appear to be killed more quickly than those which mature their fruit later in the season.

The leafhoppers become carriers of the curly top virus by feeding on wild or cultivated host plants that are affected with curly top. They then are able to transmit the disease to other plants for an indefinite period. The insects overwinter and produce their spring broods on various perennial and winter annual weeds and other host plants. Many of these hosts are susceptible to curly top and become infected through the feeding of overwintering leafhoppers that carry the virus.

When the spring broods of leafhoppers reach maturity, they migrate to weeds or other wild host plants that appear on uncropped or waste lands during the spring and summer or move to cultivated areas, where they feed on sugar beets and other susceptible crops or on weed hosts. This migration may be hastened by the maturing and drying of the plants on which the leafhoppers have bred in the abandoned or desert areas. Many of these migrating leafhoppers have acquired the curly top virus from breeding-ground hosts and transmit it to any susceptible plants on which they feed during the spring. Such hosts then serve as sources of the virus to the spring and summer broods of leafhoppers that develop on favored crop and weed hosts in and about the cultivated fields.

The severity of curly top in any given season depends on the number of insects carrying the virus to the cultivated crops and the stage of development of the crop at the time the insects feed upon the plants. A large influx of leafhoppers does not necessarily result in a severe

epidemic of curly top unless a considerable percentage of the insects are carrying the virus. This is particularly true with tomatoes, since the tomatoes are not a preferred host and the leafhoppers do not breed on the plants. For this reason tomatoes are also more likely to be injured if grown near sugar beets or other favorable hosts of the virus and the insect, since the insects may spread in sufficient numbers from such hosts to inoculate many of the tomato plants with the virus.

Recommendations for Control

There are no very satisfactory methods for the control of curly top on tomatoes. Attempts to control the leafhopper have not as yet been effective, and its control presents very serious difficulties because

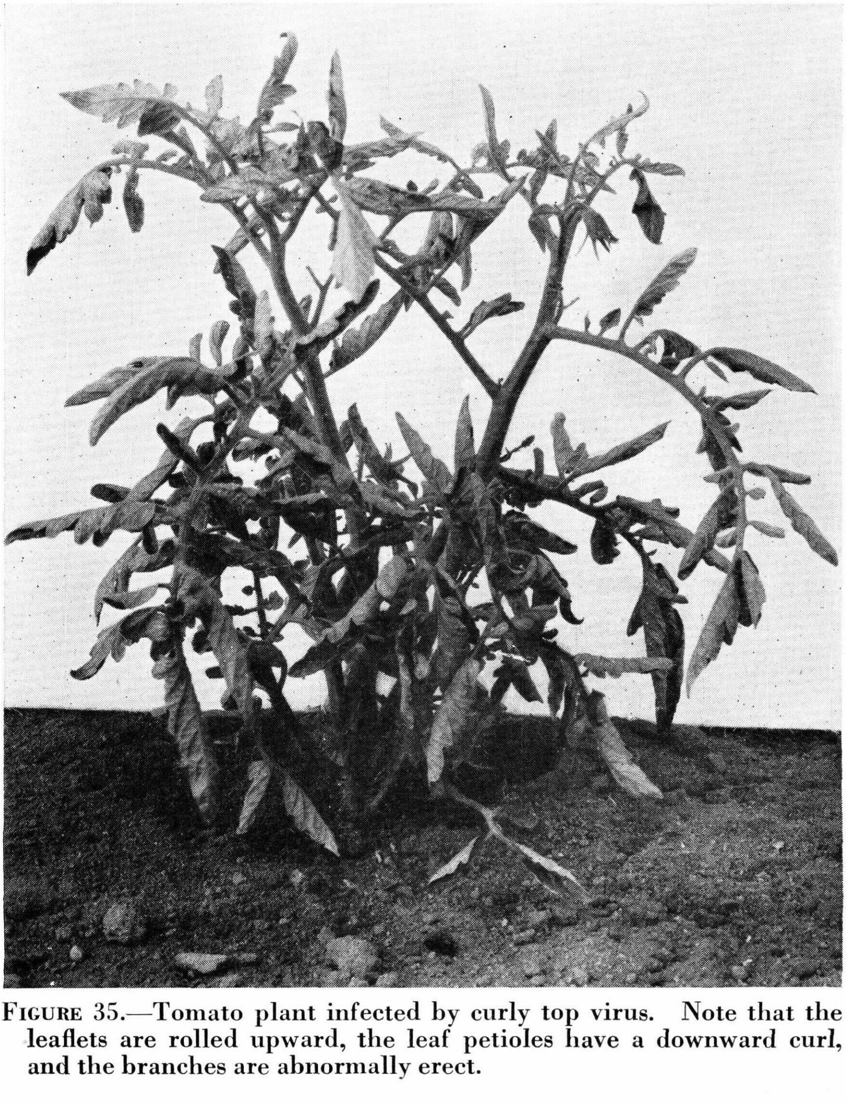

FIGURE 35.—Tomato plant infected by curly top virus. Note that the leaflets are rolled upward, the leaf petioles have a downward curl, and the branches are abnormally erect.

of the great areas of its winter breeding grounds and the difficulty of controlling such a migratory sucking insect in the fields. Roguing of diseased plants also is of little value in reducing losses from curly top, since the disease is not transmitted by contact or handling diseased and healthy plants.

All cultivated varieties of tomatoes are severely injured by the disease and, although great effort is being made to develop resistant varieties by hybridization with wild tomato species that show resistance to curly top, no resistant varieties that are suitable for commercial use are yet available.

Certain cultural practices, however, have shown at least a limited value in reducing losses from the disease. Varying the time of planting in order to avoid severe insect attack when the plants are small may reduce the amount of curly top infection in some seasons. However, no general recommendations can be made since the planting date must be adjusted to meet local climatic conditions and the probable time of migration of the leafhoppers cannot be accurately predicted. In some sections early plantings have given good results, and in others late plantings have suffered the least injury. Local experience is the best guide as to dates of planting.

The results of various experimental trials, particularly in Utah, have indicated that the use of closer planting distances in rows of normal width will more or less reduce the percentage of curly top infection and also result in an increased yield of marketable fruit. These planting methods have consisted either in setting plants at even intervals as close as 6 inches or in double-hill plantings in which two to four plants are set at distances up to 6 inches apart in hills planted in rows 42 inches apart. As a rule the amount of disease has been reduced and the yield increased as the distance between plants has been decreased. These systems entail a considerably greater cost for plants and labor in transplanting; and in years when curly top is not severe these increased costs may offset the gain from an increased yield. If these planting costs can be reduced by the development of a method of direct seeding in the field suited to the local environmental and cultural conditions, such close planting is likely to prove of considerable value. Certain types of direct seeding have been in use in restricted areas for some time and apparently have given fairly satisfactory results in reducing losses from curly top, but further work on the problem will be necessary before any general recommendations can be made.

Shading the plants under slatted or muslin-covered frames has considerably reduced the amount of curly top. The leafhopper prefers to feed on plants in the open, and shading not only tends to keep the insects away from the plants but also has an arresting effect on the development of the disease in infected plants. As a rule the infection is reduced whenever plants are grown in shaded or partly shaded locations. Some protection can also be had by covering the individual rows with tentlike strips of muslin supported by stakes or wires and anchored by covering the edges of the cloth with soil. These covers are lifted to permit weeding and are removed when the plants touch the cloth. After this stage of growth is reached, the injury from curly top usually is greatly reduced. These methods, because of the extra labor and material involved, are suited to home gardens rather than to commercial plantings.

DISEASES CAUSED BY INSECTS AND NEMATODES

PSYLLID YELLOWS

The disease known as psyllid yellows is caused by the feeding of the nymphs of a small sucking insect known as the tomato, or potato, psyllid (*Paratrioza cockerelli* (Sulc)). These insects secrete a toxic substance which is introduced into the plant during their feeding and causes serious abnormalities of growth. This disease, which also occurs on potatoes, has caused losses on tomatoes in Colorado, Utah, Wyoming, Nebraska, and other Western States. However, the injury to tomatoes, while sometimes severe in local areas, has not been of major importance.

The early symptoms of psyllid yellows consist of a thickening of the older leaves, which roll upward at the base. The petioles of the younger leaves are twisted; there is a purpling of the veins and margins of the leaflets. At the same time the leaf turns yellowish green. The younger leaves are narrowed and dwarfed and curl slightly upward at the tips. The stems and petioles are abnormally slender, and in older plants the internodes are lengthened, giving the new growth a weak, spindling appearance (fig. 36).

If the plants are affected when small, they commonly are much stunted and set few or no fruits. However, when plants are not attacked until they are well grown, there is often more than a normal number of blossoms. In such plants many fruits are set near the tips but remain small. Plants showing marked abnormalities of growth usually produce yellowish-red fruits whose inner flesh also fails to color properly. These fruits are soft and of very poor quality. Plants that show only mild psyllid injury also are likely to produce inferior fruits.

The symptoms of psyllid yellows are suggestive of those caused by a virus disease and at times may be confused with those of curly top. However, plants affected with curly top show a more pronounced yellowing and curling of the leaves and die more rapidly than those suffering from psyllid yellows. No virus seems to be concerned in the case of psyllid yellows—the plants soon show definite evidence of recovery if all the psyllids are removed. This indicates that there is no increase of the toxin in the cells of the plant, as would be the case if a virus were present. Further evidence against the virus theory is furnished by the fact that no symptoms appear unless a considerable number of the insects are feeding on the plant.

Recommendations for Control

The only means of preventing injury from psyllid yellows consists in the use of measures designed to keep the plants free from the psyllid. The following measures are recommended for preventing injury by this insect.

The plants may be dusted with 300-mesh dusting sulfur or sprayed with a mixture of 1 pound of wettable sulfur to 10 gallons of water. Spraying with a mixture of 1 gallon of liquid lime-sulfur (32° Baumé) and 4 pounds of wettable sulfur in 80 gallons of water is also effective, but this mixture may slightly damage the plants. The first applications should be made while the plants are in the seedbeds or coldframes, or, if this has not been done before the plants are set in the field, the tops of the plants should be dipped in a suspension of 1 ounce of wettable sulfur to 1 gallon of water. Further applications should be

FIGURE 36.—Young tomato plant affected with psyllid yellows. Note that the leaves are twisted and somewhat narrower than those of normal plants.

made (1) 10 days after transplanting, (2) when blossoming begins and the plants are branching, and (3) just before the plants fall over and begin to spread.

ROOT KNOT AND OTHER DISEASES CAUSED BY NEMATODES [8]

Tomatoes are subject to the attacks of various nematodes, or eelworms. These are minute, mostly eel-shaped organisms usually not visible to the naked eye. Various kinds live by the millions in the

[8] Prepared by G. Steiner, principal nematologist in charge, Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering.

croplands of the United States. Many attack plants. Unfortunately many growers are not even aware of the existence of these pests.

In this country the roots of the tomato plant may be attacked by such forms as the root knot nematode (*Heterodera marioni* (Cornu) Goodey), the golden nematode of potatoes (*Heterodera rostochiensis* Wr.), various types of so-called meadow nematodes (*Pratylenchus* spp.), reniform nematodes (*Rotylenchulus* spp.), spiral nematodes (*Helicotylenchus* spp.), and others, while stems, leaves, and fruit may harbor additional different species. The root knot nematode appears to cause the most damage. This pest occurs in many home gardens in most of the States except those in the far North. It is peculiarly abundant through the warmer sections and occurs as a greenhouse pest everywhere. It is often the cause of significant losses indoors and outdoors in commercial tomato plantings.

Eelworm damage on tomato plants is difficult to recognize because nematodes do not produce specific symptoms. Tardy growth, unhealthy appearance, wilting during the hot part of the day or during dry weather, or yellowing and stunting of the whole plant may indicate the presence of large numbers of nematodes on the roots. Roots of plants suspected of being infected with nematodes should be examined. When numerous, meadow nematodes may stunt the roots and induce the formation of an abundance of short lateral rootlets, thus producing a "bearded" appearance.

The root knot nematode is the easiest nematode to recognize. It induces the formation of galls, irregular knots, and swellings of the roots. On the tomato plant these galls may be small and hardly noticeable or large and irregular as shown in figure 37. Single females or groups of them may be found inside these galls. They appear as pear-shaped whitish bodies just barely visible to the naked eye, measuring only about one-thirtieth of an inch in diameter. A single root may contain several hundred of such females, each capable of producing 500 to 2,000 eggs within the span of 2 to 3 months. During the growing season the eggs usually hatch in a short time and the eel-shaped larvae then make their way through the soil and enter new roots. There they may grow to maturity and in time produce eggs. At a temperature near 80° F. this will take only about 25 days, while at 62° it takes approximately 87 days; below 55° the root knot nematode stops its activity. If roots of a suitable host plant are not available or if conditions are otherwise not proper for the development of this nematode, eggs may remain viable in the soil for at least 2 years. Freezing of the soil in winter usually does not kill the root knot nematode.

Seedlings and young tomato plants suffer much more from nematode attacks than older plants. It is, therefore, essential to protect the plants from invasions. After long feeder roots have been developed attacks by nematodes cause much less damage.

Recommendations for Control

Light sandy soils are preferred by nematodes. Heavy soils also may be infested, but in these the spread is much slower. Eelworm pests once established in a soil are difficult to eradicate; therefore, every effort should be made to prevent their distribution and establishment. Unfortunately man himself is the most effective distributor by transfer of infected nursery stock and infected root crops such as carrots,

beets, and potatoes, by use of tools, implements, and other equipment to which infested soil is attached, by planting infected seedlings, and in other ways. It is important, therefore, to examine carefully the roots of tomato seedlings and transplants. Discard and destroy plants with decaying and diseased roots, particularly those that have galls and swellings. To produce clean tomato seedlings, it is best to

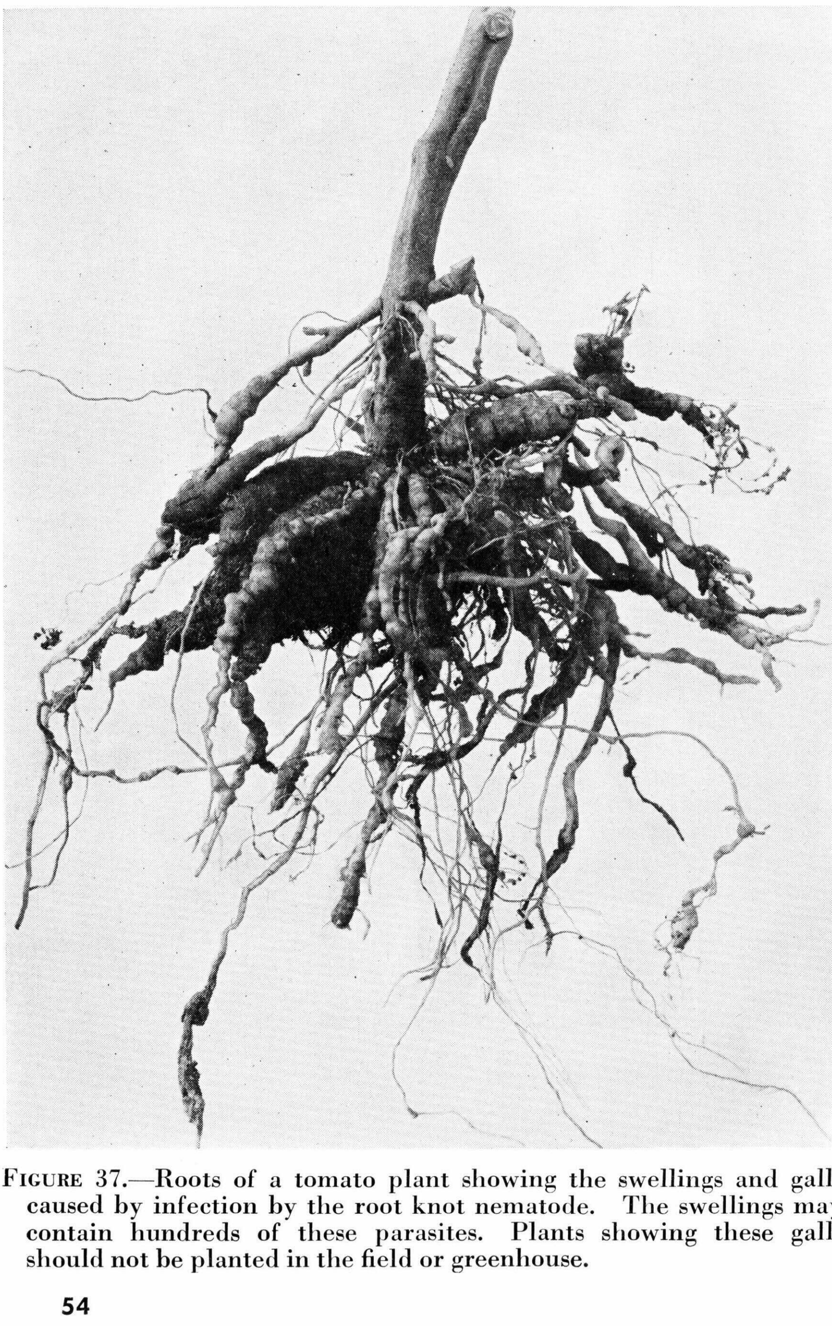

FIGURE 37.—Roots of a tomato plant showing the swellings and galls caused by infection by the root knot nematode. The swellings may contain hundreds of these parasites. Plants showing these galls should not be planted in the field or greenhouse.

grow them in sterilized soil, in soil treated with a fumigant, in vermiculite, or in peat moss.

If tomatoes have to be planted in soil known to be infested with the root knot or other nematode pests, treatment with one of the newer soil fumigants is strongly recommended. Properly done, such treatments should result in better growth, better stands, and increased yields that give returns well above the cost. For nematode control soil fumigants such as the dichloropropene-dichloropropane mixtures or mixtures containing ethylene dibromide or methyl bromide are used. Where an effective control of fungi and weed seeds is also desired and the cost of a treatment is less important, as for example, in seedbeds or potting soil, chloropicrin is recommended. (See pp. 73 and 74.)

On land infested with the root knot nematode this pest may be satisfactorily controlled through rotations with root-knot-resistant or root-knot-immune crops, such as *Crotalaria spectabilis*, beggarweed (*Desmodium molle* and *D. tortuosum*), oats, and rye. In many sections peanuts are not attacked by the race of the root knot nematode occurring there and are then an excellent rotation crop. In certain localities, however, peanuts are heavily attacked and therefore are not usable. In the South good reduction of root knot is obtained by seeding infested land with winter oats and *C. spectabilis*. After the oats are harvested, the crotalaria germinates and grows to a cover crop that is plowed under in the fall. Tomato seedlings or a regular tomato crop may be safely produced.

Attempts are being made to breed tomato varieties resistant to the root knot nematode, but no resistant varieties are as yet available.

Jimsonweed (*Datura stramonium*) is resistant to the attacks of the root knot nematode; tomato plants can be grafted to jimsonweed rootstock and so may be grown without attack by this nematode. The method, however, is not considered safe, because tests show that an alkaloid poison occurring in the jimsonweed is transferred to the tomato fruit.

Damage on nematode-infected plants can be reduced by good care. Provide enough moisture, cultivate frequently, and encourage general vigor by the liberal use of fertilizers. Heavy mulching is also said to improve the condition of infected plants.

CLOUDY SPOT

Tomatoes often show irregular, whitish to yellow spots in the tissues just below the skin. This condition, known as cloudy spot, is caused by the feeding punctures of certain species of insects of the pentatomid family, commonly called stinkbugs. Such spotting is often common locally in the Atlantic and Central States. Fruits showing these blemishes are so injured in appearance as to have a reduced market value, particularly for canning.

The spots vary from one-sixteenth to one-half inch in diameter and may be so numerous as to cover a considerable part of the fruit surface (fig. 38). If the skin above such spots is peeled back, it will be found that they consist of glistening, white masses of cells with a spongy texture. These masses of cells do not extend deep into the fruit, and no decay of the tissues follows cloudy spot. Both green and ripe fruits are found showing this injury, but it is more apparent on ripe fruits, where the spots are light yellow.

As the disease occurs rather sporadically and is of minor importance, little has been attempted in the way of control. The amount of injury ordinarily does not warrant any considerable expenditure for insecticides.

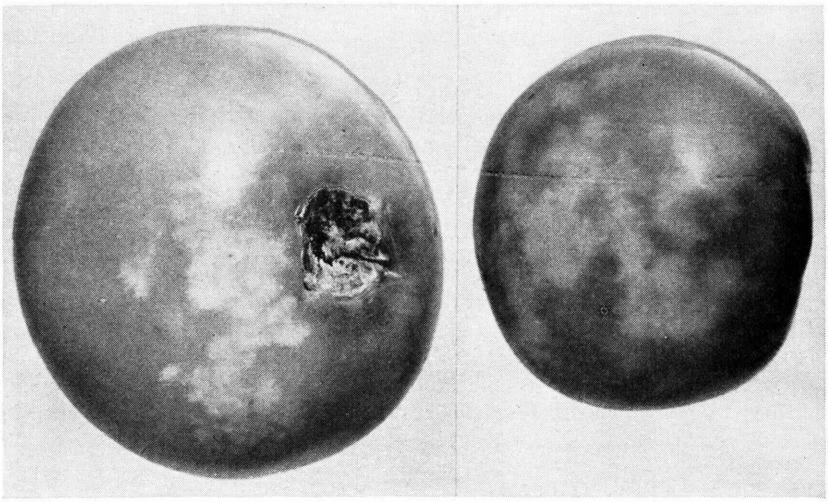

FIGURE 38.—Tomatoes showing the whitish, irregular patches just below the skin that are called cloudy spots. These are due to the feeding punctures of stinkbugs.

NONPARASITIC DISEASES

BLOSSOM-END ROT

Blossom-end rot is a nonparasitic disease of tomato fruits that causes some damage in both the field and the greenhouse. Like other nonparasitic diseases, it is not limited to any particular region and occurs wherever conditions favor its development.

Fruits are most commonly affected when a third to half grown, but they may be attacked at any stage. The first evidence of the injury consists of a brown discoloration of the tissues near the blossom end of the fruit. These spots enlarge and darken until they may cover a third to half of the surface. As they increase in size, the tissues become shrunken and the surface of the spot is flattened or concave (fig. 39). The skin of the fruit becomes black and leathery, but there is no soft rotting of the fruit unless the spots are invaded by bacteria or fungi.

Blossom-end rot occurs most commonly when the plants have grown under favorable conditions during the early part of the season and are then subject to a long period of drought at the time the fruits are in an early stage of development. Under such conditions the cells at the blossom end apparently fail to receive sufficient water to support their growth, and break-down and shrinkage of the tissues occur at this point. Although blossom-end rot is most common under the conditions just mentioned, it also occurs after periods of unusually abundant rainfall. In such instances it is possible that the soil becomes so nearly saturated with moisture that many small rootlets are killed by

lack of aeration or destroyed by certain fungi that are particularly active in moist soils. As a result the root system is so damaged that the fruits do not receive sufficient moisture. Plants that have received heavy applications of nitrogenous fertilizers, particularly manure, are likely to be especially susceptible to blossom-end rot, but the disease is also likely to cause serious damage on plants that have an insufficient supply of nitrogen and have accumulated abnormally large amounts of starch and other carbohydrates.

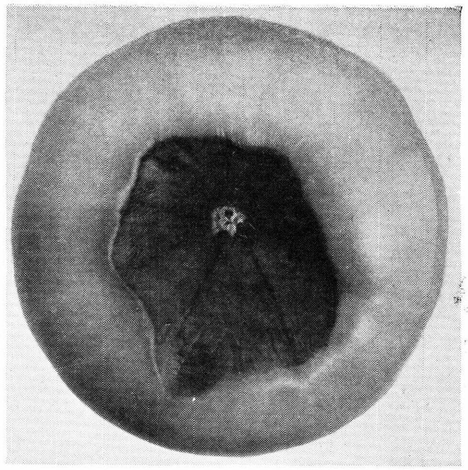

Figure 39.—Tomato showing blossom-end rot. Note that the tissues are dark and shrunken and that the surface of the spot has a dry, leathery appearance.

Recommendations for Control

Even, regular waterings will help to control the disease in the greenhouse, and the avoidance of excessive applications of nitrogen will aid in reducing losses in both the greenhouse and the field. Plants supplied with ample amounts of superphosphate and available calcium also appear to be less susceptible to the disease. The use of a complete fertilizer with calcium nitrate as a source of both nitrogen and calcium appears to aid in reducing injury from blossom-end rot. In irrigated sections and in home gardens where water can be applied more or less at will, care should be taken to maintain an even supply of soil moisture.

POCKETS

Pockets, or puffiness, is a nonparasitic disease of tomato fruits that is most common on tomatoes grown for market during the winter and early spring. It causes considerable loss in fields in Florida, Mississippi, California, and Texas and also occurs in greenhouse crops.

The fruits that are affected are light in weight and feel soft. They may be of normal shape, but often the surface is flattened or shrunken over the sections between the internal walls. When such fruits are cut in cross section the fleshy, outer wall is usually found to be normal in thickness, but the central portion containing the seed is not fully developed, and a cavity occurs between it and the outer wall (fig. 40). Decay does not necessarily occur in fruits of this sort, and there is no discoloration of the flesh, but the fruits are unmarketable because of their soft texture and poor quality.

The occurrence of pockets in tomatoes is apparently due to various environmental and nutritional factors that either interfere with normal pollination or affect the later development of the seed-bearing tissues of the fruit. Pollination may be affected by either high or low air temperatures. Both excess soil moisture and drought may possibly interfere with the normal development of the immature seeds and their surrounding tissues.

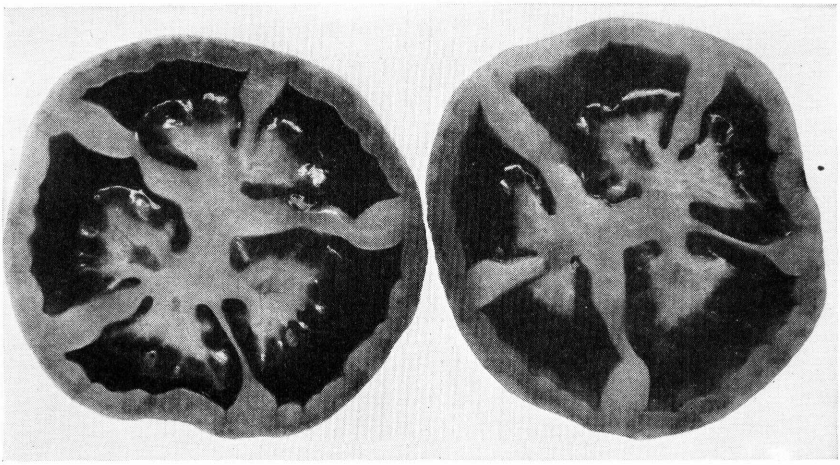

FIGURE 40.—Cross sections of tomatoes showing pockets. Note the cavities between the outer walls and the central parts of the fruit.

Recommendations for Control

Excessive applications of nitrogen appear to favor the development of pockets and should be avoided. No definite control measures can be recommended, but there is some evidence that the ample use of superphosphate and the use of only moderate amounts of nitrogen may be of some value in preventing the development of this trouble.

BLOSSOM DROP

Tomato plants often fail to set a normal crop of fruit because of the dropping of the blossoms that occurs at about the time the flowers are fully developed. This loss of blossoms may occur wherever tomatoes are grown and often causes a serious reduction in yield.

A number of environmental factors probably are concerned in causing blossom drop, but this trouble appears to be particularly prevalent when the soil moisture is low and the plants are subjected to hot, drying winds. Such conditions appear to favor an abnormal elongation of the style, and few such blossoms set fruit. Sudden periods of cool weather or beating rains also may interfere with the proper development and fertilization of the blossoms, and excessive applications of nitrogenous fertilizers may be responsible for some dropping. Loss of blossoms also results from infection by parasitic bacteria or fungi, such as those causing early blight, septoria leaf spot, and bacterial spot.

Recommendations for Control

Large-fruited varieties of the Ponderosa type are very subject to blossom drop and should not be used where summers are usually hot and dry. Summerset, a small-fruited variety developed by the Texas Agricultural Experiment Station, withstands the hot, dry weather of the Southwest better than most larger fruited varieties. Where irrigation is possible an adequate but not excessive supply of moisture should be maintained in the soil. Avoid excessive applications of nitrogen, especially during the early growth of the plant.

SUNSCALD

Sunscald may occur whenever green tomatoes are exposed to the sun but is most frequent during hot, dry weather. This injury is common on plants that have suffered a premature loss of their foliage from leaf spot diseases, such as early blight or septoria leaf spot, and is a major cause of loss from these diseases. Fruits of plants suffering from verticillium or fusarium wilt also are likely to suffer from sunscald as a result of the loss of the lower foliage. Such injury is often severe in some irrigated sections of the West. Where healthy plants are irrigated too heavily or are irrigated rather heavily just before a rain, the amount of water in the soil may become excessive enough to kill much of the older foliage. This exposes the fruit to the sun, and the resulting losses from sunscald are often severe. Fruits of healthy plants may be injured if the vines are so disturbed as to expose the fruit to the sun during hot, dry weather.

Sunscald is most common on immature, green fruit. It first appears as a yellowed or white patch on the side of the fruit toward the sun. This spot may merely remain yellow as the fruit ripens, but frequently the tissues are more severely damaged, and a blisterlike area develops. Later this shrinks and forms a large, flattened, grayish-white spot with a dry paperlike surface (fig. 41).

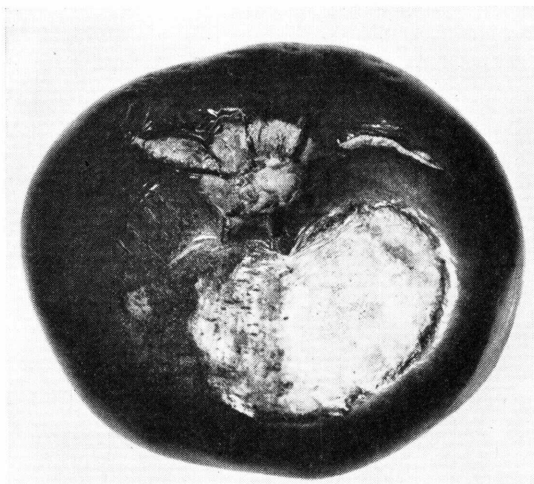

Figure 41.—Sunscald-injured tomato, showing shrinkage and flattening of the discolored surface.

Later such spots are frequently infected by fungi that produce a dark growth on the surface and sometimes cause an internal decay of the fruit.

Recommendations for Control

Unless the weather is extremely hot and dry, there is likely to be little injury from sunscald on fruits protected by a normal amount of foliage. If plants can be protected from defoliation by leaf spot diseases and attacks of fusarium and verticillium wilts, there is likely to be little sunscald damage. Where fruits are exposed, a very light covering of straw over the clusters will greatly reduce sunscald injury.

GROWTH CRACKS

Wherever tomatoes are grown, they sometimes show a cracking of the surface at the stem end of the fruit. These cracks may radiate from the stem (fig. 42) or extend more or less longitudinally around the

shoulders of the fruit. The cracks vary in depth, but often they extend deep into the flesh. Where they develop slowly the surface tissue heals and becomes fairly firm, but it is likely to rupture readily in handling. These cracks are a blemish to the fruit and also provide points of infection for the organisms causing early blight and phoma and other rots of fruit.

This cracking of the fruit appears to be most common during periods of abundant rain and high temperatures that favor an extremely rapid growth. Susceptibility to cracking varies in the different varieties of tomato, and some are characteristically subject to injury of this sort. Another type of skin cracking also occurs in fruits that have reached the ripening stage during a period of dry weather. Under such conditions heavy rain and high temperature often cause a sudden splitting of the skin that extends either radially or longitudinally about the fruit.

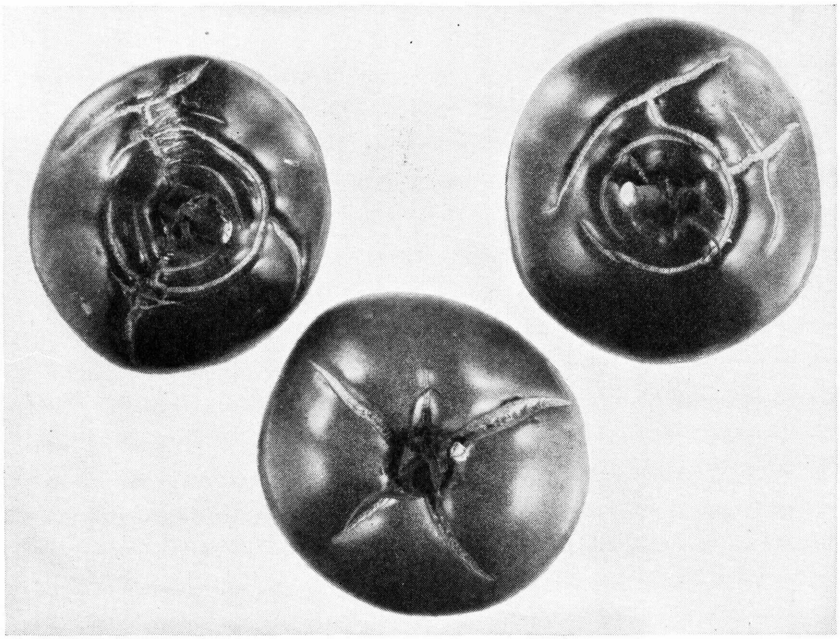

FIGURE 42.—Tomatoes showing growth cracks.

Recommendations for Control

Little can be done to control this trouble, but it usually is not severe unless unusual weather conditions favor its development. Where tomatoes are grown under irrigation no water should be applied just before harvest as this may cause excessive cracking of the ripening fruit.

CATFACE

Tomatoes frequently show extreme malformation and scarring at the blossom ends. This condition is known as catface and occurs to some extent wherever tomatoes are grown. The trouble is due to any factor that produces an abnormal development or a distortion of the tissues of the pistil of the flowers. The factors predisposing certain

plants to the production of catfaced fruits are not entirely understood, but it is known that some varieties are particularly subject to the development of such fruits. Serious disturbances to growth during blossoming, such as prolonged unseasonably cool weather, are believed to be related to such abnormalities of the fruit.

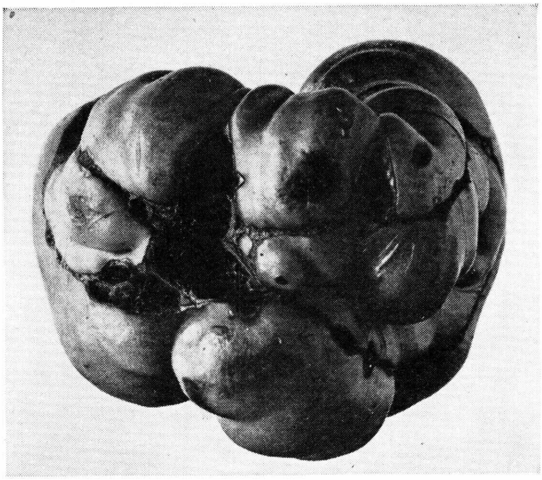

FIGURE 43.—Tomato showing severe symptoms of catface.

Fruits with this abnormality are puckered and have irregular, swollen protuberances at the blossom end. Bands of scar tissue often occur between the swellings at this point, and cavities that extend deep into the fruits are sometimes formed (fig. 43). Such fruits ripen unevenly and are unfit for market because of their appearance and poor quality.

Recommendations for Control

No means of control for this trouble are known; but, where it occurs to any considerable extent, another variety should be grown, since certain varieties are especially subject to this abnormality. However, most of the standard market and canning varieties are not ordinarily subject to much catface injury except under very abnormal growing conditions.

LEAF ROLL

During very wet seasons tomato plants frequently show an upward rolling of the leaflets of the older leaves. At first this rolling gives the leaflet a cupped appearance and continues until the margins of the leaflets touch or even overlap each other (fig. 44). The rolled leaves are firm and leathery to the touch, and one-half to three-fourths of the foliage sometimes may be affected. The growth of the plant is not noticeably checked, and a normal crop of fruit is produced.

The symptoms on tomatoes are very similar to those of a virus disease of potatoes that is also known as leaf roll, but the leaf roll of tomatoes is not caused by virus infection. Frequently leaf roll occurs when tomato plants are pruned severely, and it is very common when unusually heavy rains maintain an excessive amount of moisture in the soil for some length of time.

Recommendations for Control

Since leaf roll usually is not particularly damaging to the plant, its control is not a matter of serious economic importance. The trouble is less likely to occur on well-drained soils but may occur on any soil during periods of continued and heavy rainfall.

FIGURE 44.—Part of a tomato leaf showing typical symptoms of leaf roll.

DISEASES OF UNDETERMINED ORIGIN

FRUIT POX

The disease known as fruit pox causes small pits on the surfaces of the fruits that seriously reduce their market value and also furnish points of entry for bacteria and fungi. The disease, the cause of which is as yet unknown, has damaged green-wrap fruits in Texas and occurs in Alabama, Florida, California, Illinois, and Wisconsin.

The first symptoms are small, dark-green spots that may be only specks and rarely are over one-eighth inch in diameter. They are generally distributed over the surface but often coalesce and form streaks extending from the shoulder to the blossom end of the fruit.

The markings appear at an early stage of growth; as the fruit approaches full size, they usually become brown and have a rough, corky appearance. At this stage they may be either slightly raised or slightly sunken, forming shallow pits that give the disease its name (fig. 45). Occasionally the spots remain green and do not become roughened but turn yellow as the fruit ripens.

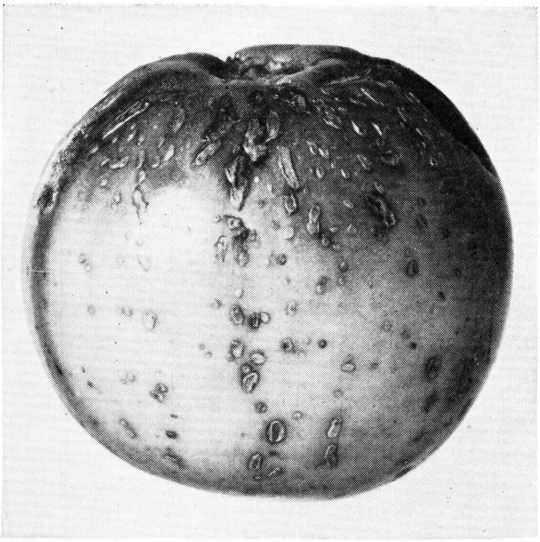

FIGURE 45.—Ripe tomato affected with fruit pox. Note that at some points the spots form streaks on the surface.

No control measures for pox are known.

GHOST SPOT

Tomatoes with small whitish rings on their surface (fig. 46) are occasionally found. These rings, which have been called ghost spots, are from one-eighth to three-sixteenths of an inch in diameter and do not extend deep into the flesh. While they are a blemish of the fruit, they do not occur commonly enough to be of much economic importance. Ghost spots have been noticed in the Atlantic and Central States and in greenhouses.

This disease has been attributed to insect punctures, as is the case with cloudy spot (p. 55), but more recently a similar marking of greenhouse-grown tomatoes in England has been shown to be caused

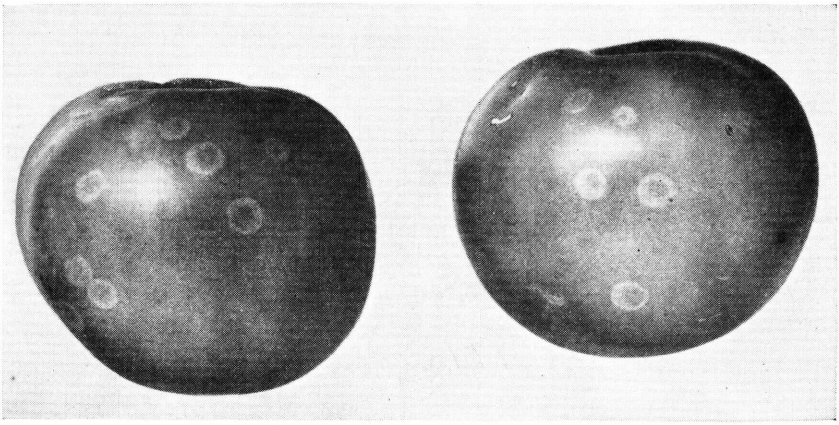

FIGURE 46.—Tomatoes affected with ghost spot. These are small, whitish, ring markings on the surfaces of the fruits.

by penetration of the surface of the fruit by spores of the fungus *Botrytis cinerea* Pers. These infections occur only when humidity is high, and apparently the fungus does not survive in the fruit. However, until the hypothesis of infection by *Botrytis* can be corroborated by similar evidence with regard to field-grown fruits in this country, it has seemed best to include ghost spot with diseases the origin of which is not definitely known.

METHODS OF DISEASE CONTROL

Since nonparasitic diseases are caused by unfavorable soil or climatic conditions, the measures available for their control are largely good cultural methods and the use of fertile, well-drained soils. Parasitic diseases, however, may be controlled by the application of a number of specific measures that will destroy the parasites or prevent their spread. Such measures are described in this section, but their specific applications have been outlined in the discussions of the various diseases.

The chemicals mentioned in the treatments are injurious to man and animals when taken internally; some of them are extremely poisonous. Therefore, care should be used in handling them to prevent their contact with the mouth, eyes, or nostrils. When these chemicals are used in dust form, care should be taken not to inhale them. When large quantities of seed are being treated with dusts, a respirator or dust mask should be worn. This warning also applies to the use of dusts on plants in the field. When small quantities of seed are treated in the open air or in a well-ventilated room the use of a respirator or mask is not necessary. When large quantities of solutions are used, oiled leather gloves and a rubber or oilcloth apron should be worn. Care should be taken in pouring out the used solution to see that it soaks into the ground and does not stand in puddles. All vessels should be cleaned thoroughly after use, and clothing and hands should be washed.

USE OF RESISTANT VARIETIES

The use of resistant varieties is the most effective and also the most economical means of disease control since it eliminates the labor and expense involved in other methods. In the case of diseases caused by organisms living in the soil it is often the only feasible method of reducing losses.

Most outstanding in respect to disease resistance are the varieties resistant to fusarium wilt (p. 6) and nailhead spot (p. 22), but commercial varieties of satisfactory horticultural quality that are resistant to leaf mold (p. 25) and verticillium wilt (p. 7) are also available. For controlling the great majority of tomato diseases, however, no resistant varieties are available, and the grower must depend on other methods to reduce losses.

CROP ROTATION

The organisms causing many tomato diseases live for various periods on decaying organic material in the soil. Too frequent cropping with tomatoes tends to maintain these organisms and to increase their

prevalence. Therefore, it is advisable that at least 3 or 4 years intervene between crops of tomatoes in any field. Tomatoes should not follow peppers, eggplants, or potatoes, as various tomato diseases also affect these crops. Weeds such as horsenettle, nightshade, jimsonweed, and groundcherry should be kept down, as they act as carriers of certain viruses and fungi.

Rotation will not insure freedom from all diseases since a number of parasitic organisms are widely distributed in the soil throughout many tomato-growing areas and some, such as the fungi causing fusarium and verticillium wilts (pp. 4 and 6), persist for long periods after they are once introduced into the soil. However, rotation is especially important in retarding the development of these wilts, since continuous cropping soon builds up these organisms in the soil to a point which renders tomato production impossible if susceptible varieties must be used.

DISPOSAL OF CROP REFUSE

From the standpoint of disease control, it is always advisable to plow under all crop refuse immediately after harvest in order to prevent further multiplication of the parasitic fungi or bacteria that are present on diseased plants. Deep plowing is important, as it tends to check the development of the organisms present on the remains of the diseased plants and so reduces the chances of later infection. In greenhouses, seedbeds, and small gardens, the removal of diseased plants is sometimes helpful in checking the multiplication of disease-producing organisms in the soil and preventing their spread to adjacent plants, but such measures are usually of limited value. Refuse from garden or greenhouse crops should never be mixed with stable refuse or used in composting soil, because such practices may introduce soil-borne organisms into fields where they previously have not occurred.

USE OF CLEAN SEED

Certain of the bacteria and fungi causing tomato diseases are often carried by the seed. Most of this seed transmission results from surface contamination during the extraction process, but occasionally organisms attacking the fruit may penetrate the seed and be carried internally. This internal infection is comparatively rare but is of considerable importance with bacterial canker (p. 9). Organisms on the surface of the seed can be destroyed by chemical treatments, but such treatments have little effect on those within the seed. The best protection against such infection consists in saving seed from healthy plants or in purchasing seed from seedsmen who can be depended on to harvest seed only from fields containing a minimum of diseased plants. The use of what is known as certified seed is of value in disease control since the seed comes from fields inspected by State agencies and certified as free from bacterial canker and certain other diseases. Fruits that are fit for use in manufactured tomato products are unlikely to contain internally infected seed. The common practice of saving seed from fruits used for such products furnishes considerable protection from internal infection since badly diseased fruits are discarded in the manufacturing process.

PREVENTION OF DISEASES IN SEEDBEDS

Wherever possible, tomato seedlings should be started in clean soil. If soil that has previously grown diseased plants must be used, it should be thoroughly disinfected before being planted (p. 70).

All flats, frames, sashes, and cloth covers should be disinfected with a solution made up of 1 gallon of commercial formaldehyde in 30 gallons of water to destroy any bacteria or fungi that may be present. If formaldehyde is unobtainable, the covers may be sprayed with copper sulfate or boiled for 10 minutes in water. Whitewash applied to sashes and frames may be of some value as a disinfectant.

Seed should be disinfected before being planted (pp. 67 to 70) and, if necessary, should be treated again for protection against damping-off fungi (p. 17).

In greenhouses, coldframes, and hotbeds proper ventilation should be provided at all times as excessive humidity favors the development and spread of seedling diseases. The seedbeds should be watered in the morning to insure more rapid drying of the leaves. Frequent light sprinkling should be avoided, and the water should be applied thoroughly at longer intervals. Seedlings should not be crowded in the beds as doing this delays the drying of the foliage and favors the spread of diseases. Plants should be handled as little as possible because handling may spread mosaic or other virus diseases if they are present on some of the plants in the seedbeds.

If seedlings are sprayed for the control of leaf diseases, it is best to use one of the fixed copper sprays (p. 76) since bordeaux mixture may sometimes cause serious seedling injury. If bordeaux mixture is used, a 4–2–100 formula (p. 77) is safest; but it should never be applied just before the plants are moved to the field since under such conditions it may cause wilting or even the death of the plants.

CONTROL OF DISEASES OF FIELD-GROWN SEEDLINGS

In the South tomato seedlings are grown extensively in the field for use in the northern canning States, and some field-grown seedlings are also produced locally in certain canning sections. To produce disease-free plants in the field the same care must be exercised as to sources and disinfection of the seed as with plants grown in seedbeds or coldframes. Since field soils ordinarily cannot be disinfected because of the expense, it is extremely important to use land that is likely to be free from nematodes and from pathogenic fungi and bacteria. Land that has not grown tomatoes or related crops for several years should be selected. In sections where the root knot nematode (p. 52) is common, no field known to have grown crops that showed noticeable nematode infestation or known to have been planted recently to nematode-susceptible crops should be used.

After the rough leaves appear, the plants should be sprayed or dusted as recommended for plants in seedbeds (above).

When grown in the field, the plants should be pulled for transplanting or shipment as soon as they reach a suitable size since the plants that are allowed to stand too long before pulling are likely to be more severely infected by the early blight fungus (p. 20). If intended for shipment, the plants should be packed as soon as possible after being pulled, as wilting seems to favor the development of early blight, collar rot, and stem canker during transit.

Seed treatments are used for two purposes: (1) To destroy disease-producing fungi or bacteria on the surface of the seed and thus to prevent seedling infection and (2) to coat the seed with a fungicide that will protect the seed and young seedlings against decay and damping-off caused by organisms in the soil (p. 16). Treatments that disinfect the seed surface do not necessarily protect against damping-off, and a second treatment may be necessary to protect against damping-off fungi. It is essential that the proper treatment be used for the purpose desired.

After treatment, care must be taken that the seed is not recontaminated by contact with untreated seed, contaminated bags, or other objects. Before old cloth bags are used they should be sterilized by being boiled in water or soaked for 10 minutes in a 1 to 30 solution of commercial formaldehyde and then dried. Small quantities of seed may be dried on paper after treatment with liquid chemicals. If larger quantities must be dried on the floor, the floor should first be disinfected or thoroughly washed with soap and water.

A number of disinfectant and protectant treatments are described in this section. Ethyl mercury phosphate (below), bichloride of mercury (p. 68), copper sulfate (p. 70), Semesan (p. 70), and the hot-water treatment are used where surface disinfection of the seed is desired. When the causal organisms also occur within the seed, either the hot-water treatment (p. 69) or the treatments by fermentation or acetic acid (p. 13) should be used. All of the other treatments described are good protectants against preemergence damping-off but are not especially effective in disinfecting the seed surface.

Regardless of the treatment to be used, care must be taken to follow directions closely in order to obtain good disease control and avoid injury to the seed. The proper seed treatments for the control of various diseases are indicated in the recommendations for their control. **(Before using chemicals, see warning on page 64.)**

Ethyl Mercury Phosphate (New Improved Ceresan)

Ethyl mercury phosphate (New Improved Ceresan) is effective in disinfecting the seed surface against the organisms causing early blight, bacterial spot, bacterial canker, and nailhead spot and against other fungi and bacteria that may cause seedling infection. It possesses an advantage over the bichloride of mercury and hot-water treatments because a residue of the chemical remains on the seed; this gives protection against attacks of damping-off fungi in the soil. It does not, however, destroy fungi or bacteria that are within the seed.

In treating tomato seed the chemical can be applied in either dry or wet form. Originally ethyl mercury phosphate was used only as a liquid soak on tomato seed, but recent work has shown that dry seed may be effectively disinfected by using it as a dust treatment. When so used, this material is applied at the rate of 0.5 percent by weight of seed. This is equivalent to 1 level tablespoonful to 1 pound of seed. Seed and dust are put in a tight container and shaken thoroughly for 3 to 5 minutes. The excess dust should always be screened off at once after treatment. Care must be taken not to inhale the dust during or after treating the seed. Seed already treated with bichloride of mercury should not be treated with ethyl mercury phosphate.

The wet treatment may be applied to either dry or freshly extracted seed. By this method the seed is soaked for 5 minutes in a 1 to 1,200 solution of the commercial compound. A solution of proper strength is obtained by adding 1 ounce of the material to 9 gallons of water in a wooden or glazed container. Metal vessels should not be used. The seed is stirred constantly and, after being treated, is poured into a loosely woven bag to drain and is dried without being rinsed. The solution should be used only once, and not more than 1 pound of seed should be used in each gallon of the solution. This treatment may be used with freshly extracted seed or with seed that has been dried before being treated. It is best not to store the seed in airtight containers after it is treated. Oiled leather gloves and a respirator should be worn when handling large quantities of seed treated with ethyl mercury phosphate.

Seed treated with this chemical is likely to be slightly delayed in germination, especially if planted soon after treatment. However, the final stand is ordinarily good, and this treatment has proved particularly valuable for tomato-seed disinfection.

Bichloride of Mercury

Bichloride of mercury (corrosive sublimate, mercuric chloride) in a 1 to 2,000 solution is an effective surface disinfectant for tomato seed, particularly against organisms that cause diseases such as bacterial canker and bacterial spot and any other parasitic fungi or bacteria that may occur on the surface of the seed. It does not supply a chemical residue that protects against damping-off fungi in the soil. To obtain such protection the seed must again be treated with one of the protectant treatments discussed on pages 69 and 70. Ethyl mercury phosphate should not be used on seed that has been treated with bichloride of mercury.

In preparing the solution of bichloride of mercury, only enamel, glass, earthenware, or wooden vessels should be used, as the chemical corrodes metal containers. Bichloride of mercury may be purchased in the form of blue tablets or as a white, crystalline powder. The tablets dissolve readily in cold water and are convenient in treating small quantities of seed since one tablet dissolved in a quart of water gives a 1 to 2,000 solution. When larger quantities of seed are treated, the powdered chemical is more economical. One ounce is dissolved in 15 gallons of water to give a 1 to 2,000 solution. Since the powdered chemical dissolves very slowly in cold water, it should first be dissolved in a small amount of boiling water and then added to the remaining water necessary to make up the solution. Three ounces of powdered bichloride of mercury can be dissolved in 1 quart of boiling water.

Not more than one-fourth of a pound of dry seed should be treated in a quart of solution; a proportional amount is necessary for larger quantities of seed. After being used once, the solution is weakened, and where only small quantities of seed are being treated, it is best to discard it. If large quantities are being treated, the solution may be tested and brought back to its original strength by the addition of more bichloride of mercury.[9]

The seed is placed in the 1 to 2,000 solution and stirred thoroughly

[9] Farmers' Bulletin 1862, Vegetable Seed Treatments. It can be purchased from Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 5 cents.

while being treated. At the end of 5 minutes it is poured into a loosely woven bag, drained thoroughly, and washed for 15 minutes in several changes of water. It is then spread in a thin layer and allowed to dry.

Freshly extracted seed may be treated in this manner, but not more than 1 quart of seed should be treated in each gallon of solution. Before the fresh seed is treated, it must be freed of excess water in order not to weaken the solution.

Hot-Water Treatment

The chemical treatments just described are effective in surface disinfection but do not affect organisms that sometimes occur within the seed. Such internal infection occasionally occurs in seed from plants suffering from early blight and certain other fungus diseases, but probably it is most important in the case of bacterial canker.

Internal infection with the organism causing bacterial canker can be controlled by the special fermentation method described on page 13, but there is available another method of treatment that should destroy any bacteria or fungi that have penetrated the seed or occur on the surface. This latter method consists in soaking the seed for 25 minutes in water heated to 122° F. The seed should be treated in small quantities in loosely woven cloth sacks that are not over half filled with seed. An accurate thermometer must be used to control the temperature very closely because germination will be seriously reduced if the temperature rises above 122°. After the treatment the seed should at once be spread out in thin layers to cool and dry. Drying the hot, wet seed by spreading it in a thin layer is perhaps the most satisfactory method, as the hot seed will dry more rapidly than that which has first been cooled by immersing it in cold water. However, if the hot seed is dried without cooling in water, it should be spread out for drying immediately after treatment.

Since the hot-water treatment involves careful handling of the seed, accurate control of temperature, and the use of proper equipment, it is ordinarily best to have the seed treated at a central treating station equipped with the necessary facilities. As germination is sometimes reduced by hot-water treatment, particularly when old or weak seed is used, a small sample should be treated and tested for germination before all the seed is treated.

This treatment does not protect against damping-off. If this protection is needed the seed must be treated again with one of the chemicals listed below and on page 70.

Arasan

Arasan (tetramethyl thiuramdisulfide, 50 percent) is a preparation that has given good control of preemergence damping-off of vegetable seeds. For small quantities of tomato seed it is used at the rate of two-thirds of a level teaspoonful to 1 pound of seed; for large quantities it is used at the rate of 0.3 to 0.5 percent by weight of seed. The seed and dust are placed together in a tight container and shaken well for 3 to 5 minutes. After this the excess dust should be screened off and the seed is ready to plant.

Spergon

Spergon (tetrachloro-para-benzoquinone, 99 percent) is used as a preventive of preemergence damping-off. For tomato seed it is used

at the rate of 0.3 percent of the chemical by weight of seed. This is roughly equivalent to two-thirds of a level teaspoonful of Spergon to 1 pound of seed. The seed and dust should be placed in a tight container and thoroughly shaken together for at least 3 minutes. The excess dust is then screened from the seed.

Semesan

Semesan (hydroxymercurichlorophenol, 30 percent) is a commercial preparation used in the treatment of vegetable seeds to prevent damping-off. In treating tomato seed, one-fourth of a level teaspoonful of the dust is used for each pound of seed; the seed and dust are mixed thoroughly in a tight container for 3 to 5 minutes. The excess dust is then screened off, and the seed is ready for planting.

Semesan may also be applied in a solution made of 1 ounce of Semesan stirred into 3 gallons of water. This is equivalent to 1 level tablespoonful of Semesan to 1 gallon of water. This liquid treatment gives control of damping-off and also acts as a rather efficient surface disinfectant.

Copper Sulfate

Copper sulfate (bluestone, blue vitriol) has proved valuable for protecting seed and seedlings against damping-off fungi in the soil. This chemical is also fairly effective as a surface disinfectant against the organisms that are controlled by treatment with ethyl mercury phosphate (p. 67) and bichloride of mercury (p. 68). The treatment for tomato seed consists in soaking the seed for at least 1 hour in a solution of 2 ounces of copper sulfate dissolved in 1 gallon of water. The seed is handled as in the liquid treatments previously described and is dried without being rinsed. Not more than 1 pound of seed should be treated in 1 gallon of the solution, which can be used more than once. Copper sulfate should be used only in earthenware or wooden vessels since it corrodes metal containers. Seed treated with bichloride of mercury or hot water can be treated with copper sulfate as a control for damping-off.

Cuprous Oxide

Cuprous oxide (Red Cuprocide, Yellow Cuprocide) is used as a dust for the prevention of seed decay and preemergence damping-off (fig. 47). It is best to use only the yellow or bright-red form of the dust prepared especially for seed treatment. It should be kept in airtight containers to avoid deterioration.

In treating tomato seed 1½ level teaspoonfuls of dust to 1 pound of seed or 1½ pounds of dust to 100 pounds of seed is used. The seed and dust are thoroughly shaken in a tight container until all the seed is well coated. The excess dust is then screened off and the seed is ready to plant.

On very acid soils there is likely to be some injury where cuprous oxide is used. Seed treated with cuprous oxide and planted in dry soils with a low organic content may show some injury from the treatment.

SOIL STERILIZATION AND DISINFECTION

Disease-producing organisms frequently are present in greenhouse, seedbed, and hotbed soils; the disinfection of such soils is a valuable means of disease control. To be effective, however, the treatment

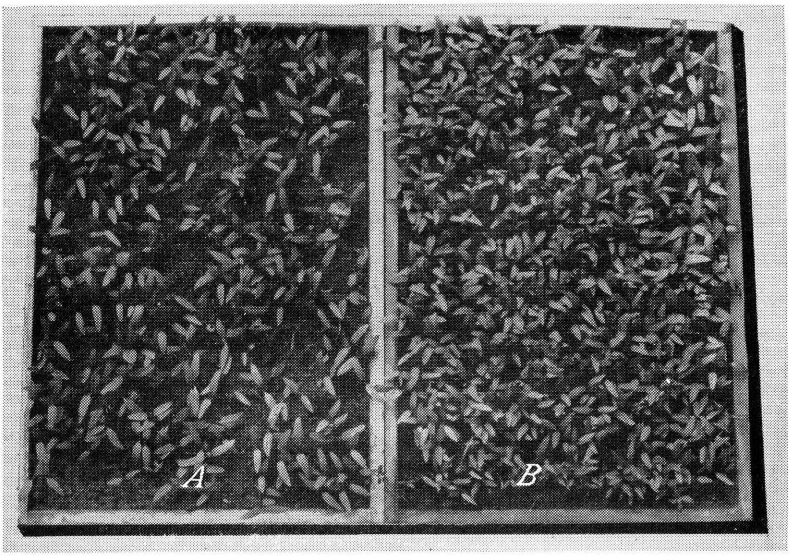

FIGURE 47.—Tomato seedlings from untreated seed (*A*) and from seed treated with cuprous oxide (*B*). (*Courtesy of the New York (Geneva) Agricultural Experiment Station.*)

must be thorough and care must be taken to prevent recontamination of the soil. The methods commonly used consist in disinfection by steam or chemicals.

Sterilization by Steam

Treatment of soils by steam is one of the most effective means of sterilization; but its use is largely limited to greenhouses, since steam is not generally available for use with hotbeds and open seedbed soils. In using steam care must be exercised to prevent recontamination of the soil, since certain pathogenic organisms, particularly damping-off fungi, may multiply rapidly if introduced into freshly sterilized soil. Tomato plants at times may be damaged if transplanted into freshly steamed soil; therefore, it is usually best to allow 2 weeks or more between steaming and planting.

In the greenhouse steam is most easily applied through a permanent system of tile 3 or 4 inches in diameter buried 15 inches in the soil in rows 18 to 24 inches apart. These tiles are attached to pipes that can be connected to a steam boiler. Steam is turned into the tile and maintained until the temperature at the surface of the soil reaches 210° F.

When such permanent systems are not available or seedbeds are to be sterilized, portable systems are used.[10] One of the most common methods consists in the use of a galvanized-iron pan 7 to 10 inches deep, 5 to 7 feet wide, and 8 to 12 feet long, according to the size of the beds. This pan is placed over the bed and the edges are forced into the soil to prevent the escape of steam. It is then connected to a portable boiler or greenhouse steam line and, after the steam is turned on, is left in place for 30 to 60 minutes, depending on the character of

[10] Farmers' Bulletin 1629, Steam Sterilization of Soil for Tobacco and Other Crops.

the soil. To insure thorough penetration the soil must be loose and contain a moderate amount of moisture. After the pan is lifted, the soil should be covered to retain the heat as long as possible.

Another method consists in burying perforated pipes in the soil in parallel lines and applying the steam from a connecting heater. The pipes are usually 1½ inches in diameter and have ⅛-inch holes drilled 1 foot apart in the bottom of the pipe. They are buried in parallel lines 1 foot apart at a depth of about 1 foot. When the soil reaches the required temperature the pipes are lifted and moved to a new location. The number and length of the pipes depend on the capacity of the boiler used.

Greenhouse benches and hotbed soils can also be sterilized by the use of a steam rake. This apparatus consists of a frame of pipe to which are fitted rakelike teeth of perforated pipe that will extend 6 inches into the soil. These teeth usually are made of ½-inch pipe with ¼-inch holes near the closed ends. The frame is of such a width as to fit best the benches or frames. The teeth are buried in the soil and steaming is continued for 30 to 60 minutes with a cover over the area steamed. If canvas is not available, newspapers may be used for covering the soil. A temperature of 210° F. should be obtained at the surface of the soil.

In steaming for the control of soil fungi or nematodes, it is often difficult to heat thoroughly the soil along runways and at the corners and sides of benches and frames. Steam sterilization is an expensive and rather laborious process; and, unless all the soil is thoroughly heated, the parasitic organisms may soon again be found infesting much of the soil. For this reason, the temperature of the soil should be taken at the points mentioned to make sure that it is thoroughly heated.

Disinfection by Chemicals

Certain chemicals are effective in destroying pathogenic fungi, bacteria, and nematodes in the soil. Chloropicrin or formaldehyde give good control of many of these organisms; treatment is expensive, however, and their use is usually limited to greenhouse and seedbed soils or small field plantings. Some other chemicals are not as effective against fungi and bacteria, but they give good control of nematodes. They are less expensive and can be used on larger areas. When soil in hotbeds or greenhouse benches is removed and replaced, the frames or benches should be drenched with formaldehyde before new soil is put in. The other chemicals mentioned are not suited for use on open frames; they should be applied only in the soil where the fumes will be released slowly into the air. **(See warning on page 74 before using these chemicals.)**

Formaldehyde Treatment

Formaldehyde is one of the chemicals used in disinfecting the soil. The so-called formaldehyde drench consists of a solution of 1 gallon of commercial (40-percent) formaldehyde in 30 gallons of water. This solution is applied at the rate of 1 quart to each square foot of soil. The soil should be fairly moist and in a loose and friable condition before the solution is applied. After the solution is applied the soil is watered heavily and kept covered for 48 hours; then the covers are removed, and the gas is allowed to escape. As soon as the soil is suffi-

ciently dry, it should be worked to hasten the escape of the formaldehyde vapor. The soil must be allowed to stand 10 days to 2 weeks before planting, and formaldehyde must never be used where the vapor will reach plants, for they would be killed by the gas.

When a small quantity of soil is to be used in flats or benches, it may be treated with a solution consisting of 1 part of formaldehyde to 5 parts of water. This is applied at the rate of one-half pint of solution to each bushel of soil. The soil is spread in a thin layer and sprinkled with the solution and then thoroughly mixed and placed in the flats or benches. It should stand for 24 hours before the seed is sown and must be thoroughly watered just as soon as the seed is planted. This treatment is quite effective in controlling damping-off, but it does not disinfect as thoroughly as the drench method. Seedlings should be transplanted into soil treated by this method only after the odor of formaldehyde can no longer be detected.

Flats, benches, or hotbed frames that are to be filled with sterilized soil must always be drenched with a solution of 1 part of formaldehyde to 30 parts of water and must stand for 48 hours before being used.

Chloropicrin and Other Treatments of Similar Type [11]

Chloropicrin is very effective for killing fungi, bacteria, and other soil-borne organisms such as nematodes. It also kills weed seeds. When soil is not placed in tight containers, this fumigant requires a water seal (that is, after application the area should be sprinkled to wet the surface of the soil to a depth of an inch or so). Therefore, its use is largely restricted to greenhouses and field areas of moderate size. For treating large areas mixtures containing dichloropropene and dichloropropane (for example, D–D and Dowfume N) and those containing ethylene dibromide (for example, Bromofume, Dowfume W, Iscobrome D, and Soilfume) are generally used. Though not highly effective against fungi and weed seeds, these fumigants when properly applied have proved very effective against nematodes. They are less expensive than chloropicrin, and they do not require a water seal.

These fumigants are applied by injecting small quantities into the soil to a depth of 6 inches at regularly spaced intervals (spot injections) or for large areas by injecting in parallel subsurface streams. Several types of hand-operated applicators suitable for treating small areas are on the market. Large-scale applications are made usually by individuals or companies engaged in the business and possessing the necessary equipment. The distance between subsurface streams or between rows of injection points, as well as the distance between injection points in the row, should be 10 inches for chloropicrin and 12 inches for the other fumigants. Somewhat wider spacing may be permissible in sandy soils. The position of injection points in adjacent rows should be staggered. The amount per injection should be 2 to 2.5 cubic centimeters for chloropicrin and 3 to 4 cubic centimeters for the other fumigants.

The soil is prepared in the same manner as for planting a crop. It should be fairly moist, moderately loose, and reasonably free from

[11] Prepared by J. R. Christie, nematologist, Division of Nematology, Bureau of Plant Industry, Soils, and Agricultural Engineering.

clods, lumps, and undecomposed crop residues. Roots of the preceding crop should have had time to decay. The temperature of the soil should be 60° F. or above. Holes left by the application should be filled promptly and the land left as flat and smooth as possible. For many soils rolling is beneficial. After chloropicrin is injected, the water seal should be applied promptly and maintained for about 2 days. The time that must elapse before it is safe to plant a crop varies greatly, depending on the kind of fumigant and the kind and condition of the soil. For most soils with moderate moisture and where soil temperature is not below 70°, 8 to 10 days for chloropicrin and 10 to 20 days for the other fumigants should be ample. The drier the soil and the higher the temperature the quicker the gases escape. Fumigants linger in cool, wet soil.

When handling soil fumigants avoid prolonged breathing of the fumes. Do not allow the liquids to remain in contact with the skin; wash them off promptly with soap and water. If the liquid is spilled on clothing, remove the garments, including shoes or gloves, without delay. Never under any circumstances take the risk of getting the liquid into the eyes or mouth. Chloropicrin is very toxic to plants and should not be used where there is danger of the fumes coming in contact with plants growing in the vicinity.

SPRAYING AND DUSTING

Value of Fungicides in Disease Control

Losses from certain diseases, particularly late blight (p. 33), early blight (p. 20), septoria leaf spot (p. 22), leaf mold (p. 25), and anthracnose fruit rot (p. 28), can be greatly reduced by efficient spraying or dusting with the proper fungicides. **(See warning on page 64 before using chemicals.)**

Some of these diseases occur in many localities every year, but they do not cause severe damage unless extended periods of rain or very humid weather are accompanied by temperatures that favor the development of the causal organisms. Except for the late blight fungus, which requires cool weather for its rapid spread, the fungi causing the worst leaf diseases and fruit rots of tomatoes develop most rapidly at temperatures of 70° to 85° F. Losses from these diseases, therefore, are most severe when there are long periods of warm, wet weather. When the growing season is hot and dry, losses are usually slight.

Since the conditions favoring extensive outbreaks of tomato diseases do not occur every year, often there are years when a profitable crop can be produced without the application of fungicides and the added return from spraying or dusting may not be large. If tomatoes are grown on soils where yields are normally low, the increased return from the use of fungicides may no more than equal the cost of application unless diseases are very prevalent. Copper fungicides tend to delay somewhat the ripening of the fruit; in the Northern States, where the growing season is short, this delay may be of considerable importance in some seasons.

All of these factors require consideration in planning a disease-control program, but the grower must not lose sight of the fact that fungicides can only prevent diseases—they do not cure them. Fungicides are needed as insurance against sudden outbreaks of disease. If the plant is not thoroughly coated with an effective fungicide when

a long period of wet weather occurs, its leaves and fruit may be so generally infected that a later application of spray or dust will be of comparatively little value in preventing loss from disease.

In the past bordeaux mixture was practically the only fungicide recommended for tomatoes. Although it possesses high fungicidal value against leaf spots, it can be injurious to tomato plants and is not very effective in the control of anthracnose. The fixed copper fungicides are less injurious to the plants than bordeaux mixture and about equal to it in the control of leaf diseases. A recently introduced organic compound (p. 77) is apparently about equal to the copper fungicides in the control of early blight and is superior to them in controlling anthracnose and leaf mold. The regular use of the fixed copper or organic fungicides is likely to show a considerably greater return in the average year than was obtained by the sole use of bordeaux mixture. Formerly it was often a question whether a regular, yearly program of spraying or dusting was particularly profitable in some localities. Now the grower should consider whether such a program may not show a profitable increase in yield and quality of fruit if the newer fungicides are efficiently applied and the applications are properly and economically timed.

Timing the Application of Fungicides

Spraying or dusting can be done most economically and effectively if the time and number of applications are determined somewhat by the amount of rainfall rather than by arbitrary fixed intervals between applications. In the field defoliating leaf diseases usually do not develop in severe form until the fruits begin to set. Unless weather conditions during the early part of the season are unusually favorable to the development of disease, the first application of a fungicide should be made about 30 days after the first cluster blooms. This occurs at about the time the plants fall over ("break"). In very dry years it may be possible to delay the first application somewhat longer, but usually it should be made at about the "break" stage. Spray applications should be repeated at about 10-day intervals, depending on the weather. If rain occurs frequently, the interval should be shortened to 5 or 7 days. For dusts the interval between applications should not be more than 7 days and during rainy periods it should be even less. The number of applications will be determined to some extent by the rainfall, but at least four should be made, and it is best to plan on five during the average season.

Methods of Application of Fungicides

In spraying or dusting tomatoes it is essential to have efficient power machinery, since their growth habit makes it difficult to cover the inner leaves during the latter part of the season. Good coverage of these leaves is necessary for disease control. The foliage cannot be properly covered unless the rows are far enough apart for the passage of the machine and the plants are spaced well apart in the row. Many growers space the plants too close for proper spraying and for the best yields. Spacings of 6 by 3 feet or 5 by 3½ feet are often recommended and have given good results. When plants are spaced in either of these ways, their foliage will dry more rapidly after rain or heavy dew. Rapid drying is an important factor in reducing losses from disease.

Spraying machines should apply 150 to 200 gallons of spray per acre at 300 pounds' pressure. When the plants become large, 200 gallons of spray per acre probably will be needed for proper coverage. Machines of the type used for spraying potatoes are adapted to use with tomatoes. When the plants are small, three nozzles per row are probably sufficient; with larger plants, four nozzles are likely to give better results. Two of these four should be above the plants.

Sprays usually give better results than dusts, partly because of better sticking; however, dusting can be effective if the fungicide is properly applied. A dusting machine should deliver a steady and uniform cloud of dust, and 40 to 50 pounds of dust should be applied per acre. In order to obtain good coverage of the plants and sticking of the dust, dusting should always be done in the early morning or toward evening when the air is still and the plants are likely to be wet with dew.

Fixed Copper Sprays

The fixed, or insoluble, copper compounds include copper oxychloride sulfate, basic copper sulfates, copper oxychloride, copper oxide, and various other preparations. These are generally proprietary compounds, which are sold under trade names. They are somewhat more expensive than bordeaux mixture but are more easily prepared. Since no lime is used, they generally are less injurious to the plant than is bordeaux mixture. For this reason they are particularly recommended for seedbed spraying, since they are less likely to cause wilting of plants sprayed a few days before transplanting.

The copper content of these materials varies from 25 to 85 percent. As field sprays they usually are prepared on a basis that gives the equivalent of 2 pounds of copper (calculated as metallic copper) to 100 gallons of water. In the case of copper oxide, however, it is best to reduce the amount of copper to 1½ pounds to 100 gallons of water. In spraying seedbeds with fixed coppers, the strength should be the same as that recommended for use on the plants after they are in the field. The copper content of the different compounds is shown on the package, and the amount of material needed can be calculated from this figure. For example, 8 pounds of a compound containing 25 percent of copper would be needed to give 2 pounds of copper in 100 gallons of spray in the field, whereas only 4 pounds of one containing 50 percent of copper would be used. If the material contained 80 percent of copper, only 2½ pounds would be needed for 100 gallons. Before using the fixed copper compounds the grower should consult his county agricultural agent or agricultural college workers as to the compounds that have proved most effective under local field conditions.

Fixed Copper Dusts

The fixed coppers also are used as dusts and seem to be fairly satisfactory in this form. Dusts containing 5 to 7 percent of actual copper are recommended for use on tomatoes, but 7 percent is preferable. If a compound containing 50 percent of actual copper is used, a 7-percent dust would contain 14 pounds of the fixed copper compound and 86 pounds of talc, pyrophyllite, or some other light, inert material. Fixed copper dusts can be purchased from dealers in agricultural supplies or can be prepared at home. Dust sticks better if applied when dew is on the foliage.

Bordeaux Mixture

Bordeaux mixture consists of copper sulfate and hydrated lime in water. As a fungicide it is equal to the fixed copper compounds, but it often injures tomato plants. The injury seems to result from an increased loss of water from the foliage, which appears to be due to some effect of the lime in the mixture. Young plants are most subject to injury; seedlings sprayed with bordeaux mixture just before transplanting may wilt or die after they are set out. On large plants the injury is likely to be less severe, especially when there is ample moisture in the soil.

Until recent years the most common formula for bordeaux mixture was 8 pounds of copper sulfate and 8 pounds of lime in 100 gallons of water. This is known as an 8–8–100 mixture; the first figure indicates the amount of copper sulfate, the second lime, and the third water. Various other strengths of bordeaux mixture, particularly one containing 8 pounds of copper sulfate but only 4 pounds of lime to 100 gallons of water, are now commonly used, and many experiment stations report that this low-lime bordeaux mixture is less injurious than the 8–8–100 one. A 6–6–100 and a 6–3–100 mixture are also used. Bordeaux spray is not recommended for tomato seedlings, but if it must be used a 4–2–100 formula is advised.

All strengths of bordeaux mixture are prepared as described here except that different amounts of copper sulfate and lime are used. A stock solution can be made by placing 50 pounds of copper sulfate in a loosely woven bag and suspending it in 50 gallons of water in a wooden barrel. (Never use a metal container.) If the bag is suspended high in the water all the chemical will disolve overnight. Then each gallon of stock solution will contain 1 pound of copper sulfate. In making 100 gallons of an 8–4–100 bordeaux, for example, 8 gallons of the stock solution is added to 50 gallons of water in the spray tank; 4 pounds of hydrated lime manufactured especially for spraying is made into a thin paste and washed through the tank screen with enough water to make 100 gallons. While this is being done, the mixture must be agitated vigorously. Bordeaux mixture should always be used immediately after it is prepared because it deteriorates on standing.

A finely powdered form of copper sulfate that dissolves rapidly in water and thus simplifies mixing is available. The required amount of this copper sulfate snow is placed in the screen of the tank and is dissolved by running in enough water to fill two-thirds of the tank. The solution is kept agitated while the lime paste is washed in with enough water to fill the tank.

The materials needed to make 3, 50, and 100 gallons of an 8–4–100 bordeaux mixture follow:

Material:	*3 gallons*	*50 gallons*	*100 gallons*
Copper sulfate	4 ounces	4 pounds	8 pounds
Hydrated lime	2 ounces	2 pounds	4 pounds
Water	3 gallons	50 gallons	100 gallons

Zinc Dimethyl Dithiocarbamate

Zinc dimethyl dithiocarbamate (Zerlate, Zimate, or Karbam-white) is a new organic fungicide that seems about equal to the copper compounds for control of early blight (p. 20) and superior to them for the control of anthracnose (p. 28) and leaf mold (p. 25). It is not

recommended for the control of late blight (p. 33). If it is used early in the season for the control of early blight or anthracnose, it should immediately be replaced by a copper fungicide or by one of the organic fungicides recommended for control of late blight whenever this disease threatens to appear. For a spray 2 pounds of this compound is added to 100 gallons of water. No lime is used. For a dust 10 pounds of the organic compound is mixed with 90 pounds of some fine, light inert material such as talc or pyrophyllite.

Ferric Dimethyl Dithiocarbamate

Ferric dimethyl dithiocarbamate (Fermate, Karbam-black) is an organic fungicide that has been effective in the control of anthracnose (p. 28) but has not proved satisfactory in controlling early blight (p. 20). It is used at the rate of 2 pounds to 100 gallons of water. When it is used for the control of anthracnose it is best to apply alternate sprays of the organic material and a fixed copper, beginning and ending with the organic compound. It is not effective in controlling late blight.

Disodium Ethylene Bisdithiocarbamate

Disodium ethylene bisdithiocarbamate is a recently introduced organic fungicide that appears to be effective in controlling late blight (p. 33). This material has commonly been used in liquid form (Dithane D–14). In making the spray, 2 quarts of the liquid fungicide is added to 100 gallons of water. To this are added first 1 pound of zinc sulfate dissolved in water and then one-half pound of hydrated lime. The spray is then ready for use. (See zinc ethylene bisdithiocarbamate.)

Zinc Ethylene Bisdithiocarbamate

Zinc ethylene bisdithiocarbamate (Dithane Z–78, Parzate) is a new organic compound that is closely related to the zinc sulfate reaction product of disodium ethylene bisdithiocarbamate. It does not require the addition of zinc sulfate or lime and seems to be equal to Dithane D–14 as a control for late blight. It should be used as directed by the manufacturers.

IDENTIFICATION OF TOMATO DISEASES

A key has been prepared to aid in distinguishing tomato diseases found in the field and the greenhouse. After a preliminary identification has been made with the key, the more complete description of the disease, together with the measures recommended for its control, can be consulted on the page indicated. The brief descriptions in the key are usually followed by numbers in parentheses, which refer to groups of States indicated by the same numbers on the map (fig. 48). These numbers indicate the regions where the disease often causes serious losses or occasional losses of minor importance. Many diseases, however, are occasionally found in States not included in the list of regions given in the key. In general, the letter G indicates that the disease in question may occur on tomatoes wherever they are grown in the greenhouse. However, certain greenhouse diseases are as yet somewhat localized in occurrence.

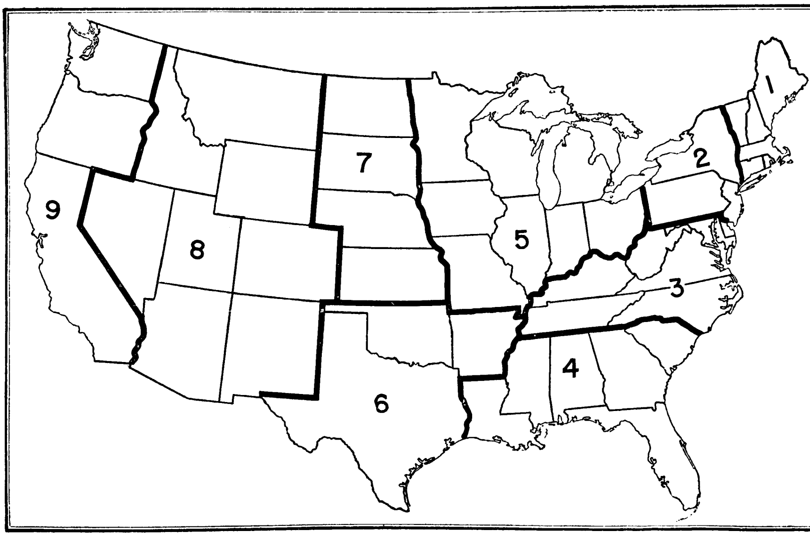

FIGURE 48.—Map of the United States showing tomato-growing regions to which the numbers in the key refer.

A KEY TO TOMATO DISEASES

DISEASES AFFECTING LEAVES AND STEMS, WITH OR WITHOUT SYMPTOMS ON FRUITS.

A. *Diseases characterized by wilting of plant, without definite leaf spots; with or without spotting or decay of fruits.*

(a) Yellowing, wilting, and death of leaves from the base upward, followed by wilting and usually by gradual death of plant. Single shoots often killed before serious infection of others. Dark-brown discoloration of woody tissues just below green outer cortex of stem. No soft decay of stem. No spotting of fruits, but sometimes discoloration of their water-conducting vessels. (2, 3, 4, 5, 6, 7, 8, 9, G.) ---------------------------- **Fusarium wilt** (p. 4).

(b) Yellowing, wilting, and loss of foliage, confined largely to bases of shoots. Slight wilting of plants during day. All branches uniformly affected. Plants stunted but usually live throughout the season. Discoloration of woody tissues of stem, generally confined to lower part. No soft decay of stem and no spotting of fruits. (1, 2, 8, 9, G.) ---------------- **Verticillium wilt** (p. 6).

(c) Rapid wilting of entire plant without yellowing of leaves. Dark water-soaked decay of central portion of stem just above ground line, followed by death of plant. No spotting of fruits. (2, 3, 4, 5, 6.) ---------------------------------- **Bacterial wilt** (p. 8).

(d) Wilting and upward rolling of margins of leaflets; usually only one side of leaf affected at first. Leaves browning, withering, and dying but remaining attached to stem. Dying of leaves progressing up the stem; one side of the plant often attacked first. Stems with open cankers and yellowish, mealy decay of inner tissues. Bird's-eye spotting of fruits; spots $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter; small cavities in central portions of fruits. (Occasional wherever tomatoes are grown.) ----------------------- **Bacterial canker** (p. 9).

(e) Gradual drooping and eventual dying of leaves over entire plant without marked yellowing of foliage. Stem decayed at ground line and covered with whitish fungus growth, with small, light-brown sclerotia. Fruits on the ground sometimes destroyed by the fungus. (3, 4, 6.) ----------------- **Southern blight** (p. 14).

(f) Slow wilting and eventual death of plant; soft tissues of the stem decayed, with cavities that contain a grayish-white fungus growth and large, black sclerotia. Fruits sometimes showing watery soft rot. (4, 6, G.) ------------------------ **Stem rot** (p. 15).

(g) Emergence failure or collapse and wilting of seedling plants caused by decay of stem at ground line or of roots. (Wherever seedlings are grown.) ------------------------------ **Damping-off** (p. 16).

B. Diseases characterized by leaf spots but no wilting of plant; with little or no spotting of fruits.

(a) Older leaves showing numerous small, roughly circular spots 1/16 to 1/8 inch in diameter, with dark margins and gray centers dotted with minute dark specks. Plants often seriously defoliated and fruits exposed to sun. **(1, 2, 3, 4, 5, 6, 7.)** **Septoria leaf spot** (p. 22).

(b) Large, yellowed patches on upper surfaces of older leaves; olive-brown, velvety coating of the fungus on undersurfaces of these spots. Much of foliage killed. Fruits rarely infected. (Most serious in greenhouse, but occasionally so in field; 2, 3, 4, 5, 6, G.) **Leaf mold** (p. 23).

(c) Numerous small, dark-brown spots extending through the leaf; spots enlarging to 1/8 inch and centers becoming grayish brown with a glazed appearance. Yellowing, withering, and dropping of severely spotted leaves. Seedlings severely injured; large plants sometimes losing much of their foliage. (Chiefly Florida, South Carolina, and Georgia.) --------------- **Stemphylium leaf spot** (p. 25).

C. Diseases characterized by leaf spots and spotting or decay of fruits, but no wilting of plant.

(a) Rather large, dead spots, 1/4 to 1/2 inch in diameter, on older leaves; spots brown with concentric rings. Plants partially defoliated. Circular to elongate, dark spots with light centers on stems. Seedlings showing partial girdling of stems at ground line. Fruits developing large, dark, leathery spots near stem ends, with dark, dry decay of flesh beneath, extending to some depth. (1, 2, 3, 4, 5, 6, 7, 9.) ------------------------------ **Early blight** (p. 17).

(b) Leaf and stem symptoms almost identical with those of early blight. Fruits showing small, slightly sunken spots with dark margins and roughened, grayish-brown centers. Spots 1/16 to 3/8 inch in diameter, occurring at any point on fruits. Decay not extending deeply into fruit. (3, 4, 6.) --------------- **Nailhead spot** (p. 20).

(c) Small, dark, irregular, greasy-appearing spots on leaves, about 1/8 inch in diameter and often tearing out. Defoliation sometimes serious. Spotting of green fruits only; small, raised, water-soaked spots, later becoming slightly sunken and light brown, with scabby, roughened surface. Spots 1/8 to 1/4 inch in diameter, not extending deeply into fruit. (2, 3, 4, 5, 6, 7.) ------ **Bacterial spot** (p. 28).

(d) Numerous minute, dark spots on leaves extending to lower surface. Fruit symptoms most noticeable, consisting of very small, dark-brown, slightly raised specks less than 1/16 inch in diameter, scattered thickly over surface. Sometimes occurring with bacterial spot. (2, 3, 4, 5, 6, 7.) ----------------- **Bacterial speck** (p. 29).

(e) Greenish-black, water-soaked patches on older leaves, increasing in size rapidly and sometimes killing much of the foliage. Water-soaked spots on fruits; spots enlarging rapidly and sometimes covering half the surface. Spots becoming brown with a firm corrugated surface and margin more definite than in buckeye rot. (1, 2, 3, 4, 5, 6, 9, G.) ----------------------- **Late blight** (p. 31).

(f) Many small, irregular, dark spots, enlarging and developing concentric markings similar to those of early blight, on leaves. Spots often coalescing and leaves sometimes shriveling. Dark-brown, elongated spots with faint, zonate markings on stem. Seedlings sometimes severely damaged. Small (1/8-inch), depressed, brown spots near stem scars on fruits in field. Larger black spots with a leathery appearance on fruits ripening after shipment. Spots

enlarging to ½ to 1½ inches and dotted with minute pustules. (3, 4, 6.) ---------------------------------- **Phoma rot** (p. 33).

(g) Green mottling of leaves accompanied by numerous small, grayish-brown, papery spots; withering and drying of some leaves in early stages of disease. Later growth mottled green and yellow with small, irregular chocolate-brown spots. Dark-brown narrow streaks of various lengths on stems. Brown, irregular, greasy-appearing surface spots ⅛ to ⅜ inch in diameter on fruits. (Occasional wherever tomatoes are grown, but most serious in greenhouse.) ---------------------- **Double-virus streak** (p. 42).

(h) Small, irregular, dark-brown lesions or linear "oak leaf" markings on leaves. Later leaf growth often showing only green mottling. Stem sometimes showing broad, brown streaks of considerable length and brown, shriveled areas in pith. Fruits not mottled but sometimes marked with depressed, brown rings about ½ inch in diameter. (Not common in field, but occasionally serious in greenhouse.) ---------------------- **Single-virus streak** (p. 44).

(i) Young leaves showing numerous small, dark, circular spots and a peculiar bronze; such leaves sometimes turning dark and withering. Tips of young plants showing dark streaks and sometimes killed. New growths sometimes much stunted. Ripe fruits showing spots about ½ inch in diameter, marked with concentric, circular bands of red and yellow. Centers of spots often raised; fruits with a rough appearance. (2, 3, 5, 9, G.) ----- **Spotted wilt** (p. 45).

D. Diseases characterized by mottling, yellowing, curling, or malformation of leaflets and usually by more or less stunting of plant; with or without symptoms on fruits.

(a) Green or yellow mottling of leaves; some curling, malformation, and dwarfing of leaflets. Plants slightly stunted. Fruits mottled by yellow strains of virus. (Wherever tomatoes are grown.) **Tomato (tobacco) mosaic** (p. 37).

(b) Pronounced stunting and bushy growth of plant. Mild, green mottle of leaflets accompanied by marked filiform malformation ("shoestring"). Only a few small fruits produced. (Occasional wherever tomatoes are grown.) -------- **Cucumber mosaic** (p. 39).

(c) Plants yellowed and stunted, with abnormally erect stems. Upward rolling of leaflets exposing undersurface. Veins purple and leaves stiff and leathery. Petioles curved downward and leaflets twisted. Many roots and rootlets killed and plants often dying. Few or no fruits produced after infection. (6, 7, 8, 9.) **Curly top** (p. 47).

(d) Older leaflets thickened and rolled upward at base. Leaflets yellowish green with purple veins and margins. Young leaves narrow, dwarfed, and curled upward at tip. Abnormally numerous blossoms; fruits yellowish red and soft. Symptoms somewhat like those of curly top, but disease developing more slowly and plants not rapidly killed. (7, 8, 9.) ------ **Psyllid yellows** (p. 51).

(e) Plants dwarfed, sickly, and sometimes wilting readily in dry weather; frequently killed. Roots showing swellings or galls. (Occasional wherever tomatoes are grown; common: 3, 4, 5, 6, 8, 9, G.) ------------------------------------ **Root knot** (p. 52).

(f) Leaflets of older leaves rolling upward and inward at margins; no yellowing or dwarfing of leaflets. Little or no stunting of plants. Fruits of normal size and color. (Occasional wherever tomatoes are grown.) ----------------------------------- **Leaf roll** (p. 61).

DISEASES AFFECTING ONLY THE FRUITS.

A. Diseases characterized by rot of the fruit.

(a) Uninjured ripe fruits showing slightly sunken water-soaked, circular spots becoming darker than the surrounding tissue. Older spots about ½ inch in diameter and showing concentric markings. Centers sometimes tan, with dark specks; in wet weather often colored pinkish by masses of spores. (2, 3, 5, 6, 7.) **Anthracnose** (p. 27).

(b) Grayish-green or brown, water-soaked spots with smooth margins, often covering half of fruit surface; most common on those in contact with soil. Spots commonly showing broad concentric bands of darker brown. (1, 2, 3, 4, 5, 6, 9, G.)
Buckeye rot (p. 30).

(c) Sunken brown spots ¾ to 1¼ inches in diameter, with narrow, dark, concentric markings on fruits in contact with or near soil. Spots smaller and zonate bands narrower than those in buckeye rot. Centers of spots sometimes breaking open. (Wherever tomatoes are grown in the field.) ---------- **Soil rot** (p. 35).

(d) Rots occurring chiefly on fruits showing mechanical injuries, growth cracks, insect punctures, spotting due to other diseases, or any other injury to epidermis. Often accompanied by odor of fermentation. (Wherever tomatoes are grown.) - **Minor fruit rots** (p. 36).

(e) Shrinking of tissues at blossom end of fruit, causing a dark, flattened or sunken, leathery-appearing spot, sometimes including half of fruit. (Whenever tomatoes are grown) -- **Blossom-end rot** (p. 56).

B. Diseases characterized by cracking, spotting, or malformation of fruits, but by no rot except from secondary infections by decay-producing organisms.

(a) Large yellow or whitish patches on portions of fruits exposed to sun. Spots remaining firm or shrinking and forming pale, flattened areas with grayish-white papery surface. (Wherever tomatoes are grown in the field.) ---------- **Sunscald** (p. 59).

(b) Cracking of fruits at stem ends, extending either radially or longitudinally. Cracks generally healing. (Wherever tomatoes are grown.) ---------- **Growth cracks** (p. 59).

(c) Fruits deformed and showing swollen protuberances at blossom ends. Masses of scar tissue between swellings; cavities extending into fruits. (Wherever tomatoes are grown.) ---------- **Catface** (p. 60).

(d) Fruits slightly flattened at sides, soft, and light in weight. Large cavity between outer wall and central portion of fruit. (Wherever tomatoes are grown; frequent occurrence: 4, 6, 9, G.)
Pockets (p. 57).

(e) Irregular whitish to yellow spots $\frac{1}{16}$ to ½ inch in diameter, just below epidermis of fruit. Spots showing glistening white masses of cells upon removal of skin. (1, 2, 3, 4, 5, 6.) ---------- **Cloudy spot** (p. 55).

(f) Small, shallow, roughened pits scattered over fruit, often massed and forming streaks extending from shoulder toward blossom end. No rot. (4, 5, 6, 9.) ---------- **Fruit pox** (p. 62).

(g) Whitish rings about ⅛ to $\frac{3}{16}$ inch in diameter scattered over surface of fruit. (Occasional.) ---------- **Ghost spot** (p. 63).

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